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## Free Xmas Supplement i-TRIXX Collection 2008



# Messaging Spin Top

## ... a striking gadget !

- Hi-Fi Wireless Headset
- Dot net on a Chip

... POWER LED DRIVER ... BASCOM AVR ... OM



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# RS EMBEDDED DEVELOPMENT PLATFORM




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# EasyPIC5 is a world-class tool that enables immediate prototype design...

**mikroICD** - Hardware In-Circuit Debugger on-board enables easy debugging

High-Performance **USB 2.0** On-Board Programmer

**User-Friendly** PIC development system

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## Rejected!

I am often asked why such and such an article proposal was rejected for publication in Elektor and methinks it's a good idea to use this space to explain a bit about the background. First, however, I should mention that unlike some of our competitors, Elektor does accept articles from anyone from anywhere, which is another way of saying that making it into print and reaching a million or so fellow enthusiasts or industry workers via a multi-lingual magazine is not limited to "the happy few", "approved authors", or similar. Anything that hits our email boxes is in principle considered for publication, brushing up and/or post-engineering by our lab, no matter if the piece is poorly written or the prototype built on perfboard — in general we are good humoured with a keen eye for originality.

However! There are a few reasons for not accepting a contribution, which inevitably get stamped.

Like this: uninventive use of components (OLD HAT); use of obsolete components (GONER); rehashing manufacturer's datasheets (REGURG) or old Elektor articles (!) (E-COPY-CAT); vague circuits nicked from websites (I-COPY-CAT), poor electronic design (DREAMON) and attempts to use the magazine as a sales pitch for products (MARCOMM). If it seems these qualifications are unkind or perhaps disparaging, you should know that they originate from engineers and editors with a total of 100 or so years experience in the business, happily applying the lingo that tends to set them apart from language purists and marcomm people.

As a good number of authors (from as far away as Iran) have already discovered, reading the *Author Guidelines* posted on our website (under the Service tab) is an excellent way of dodging our stamps, and I'm told that supplying a working prototype, some photos and comprehensive copy in an organised way, is the ticket to success.

Even if an article proposal is sadly rejected for publication, its keywords, key components, design method(s) and of course author contact details are stored in a wiki-ish repository maintained by our lab workers on a hijacked part of our server. In this way, the wiki, if challenged with a suitable query, can be used to consult potential authors and maybe trigger them to cover their favourite subject in a different way if so required.

Reject we may — neglect, we don't.

Jan Buiting
Editor

# Messaging Spin 16



## Free! 24-page i-TRIXX Supplement

starts on page 45

## 32 Hi-fi Wireless Headset




Although they've been on the shelves of audio and video equipment retailers for quite a few years now, wireless headsets have been conspicuously absent from hobby electronics magazines. It has to be said that building this sort of headset, especially if we set ourselves a certain level of quality, is far from simple — or rather, was far from simple, until some recently-brought-out modules came along to help us out.



# CONTENTS

Volume 34
December 2008
no. 384

# Top

If you fit a line of LEDs on a circular PCB and power them on continuously, they generate rings of light when the board is spun. If you add a microcontroller, you can use the same set of LEDs to obtain a more interesting effect by generating a 'virtual' text display. This article also describes a simple technique for using the Earth's magnetic field to generate a synchronisation pulse. The potential applications extend from rotation counters to an electronic compass.

## 80 Universal User Interface Module



This module provides a simple user interface for extending microcontroller-based circuits. Graphics and text display commands can be sent to it over a serial interface, and, using its UART, the module reports back when the state of any of six inputs changes. Additional firmware can display a slideshow of images stored on an SD card.

**Thanks for supporting us in 2008 and Best Wishes for the Festive Season from all Elektor staff!**

## 96 Omni Pendulum




Most people seem to think that the only thing digital electronics is good for is blinking LEDs. There is no easy to way to interface a microcontroller to the real world without some arcane 'input stage' with amplifiers and filters. This project is different. The microcontroller in it is directly connected to a small coil — and there is nothing else (except, maybe, a power source and some noise suppressing capacitors). And yet it manages to achieve something that's almost impossible with any kind of traditional analogue setup: perpetual motion.

## projects



## technology



## info & market



## infotainment

# elektor international media

Elektor International Media provides a multimedia and interactive platform for everyone interested in electronics.
From professionals passionate about their work to enthusiasts with professional ambitions.
From beginner to diehard, from student to lecturer. Information, education, inspiration and entertainment.
Analogue and digital; practical and theoretical; software and hardware.




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*Elektor aims at inspiring people to master electronics at any personal level by presenting construction projects and spotting developments in electronics and information technology.*

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## Elektor Workshop Feedback (1)

Dear Elektor — I felt it was important to thank Elektor (and the guys at Birmingham City University) for the wonderful workshop (Graphical Programming of Microcontrollers Using Flowcode, *Ed.*) on Saturday (October 4, 2008, *Ed.*)! I learned so much, and had a great time. Everyone was very friendly and helpful, which was great as I was so nervous before the workshop started, especially being the youngest there (15)!
The workshop went at a very nice pace, not being too technical, whilst being informative and interesting. I was very impressed with the amount of material given out, as this helped greatly when at home. The venue and tutors there were great, and the whole event was extremely professional. I look forward to the new E-vents, and if relevant to what I am doing, I will not hesitate to register!
**Conor Riches (United Kingdom)**

*So when will you submit your first article for publication in Elektor, Conor?*

## Elektor Workshop Feedback (2)

Dear Elektor — I would like to thank you for the course held on Saturday (PIC Programming using C, October 4, 2008, *Ed.*). A lot of ground was covered and I enjoyed it. Now all we need is a follow up course to put the words into action.
**John De Quincey (United Kingdom)**

## Elektor Workshop Feedback (3)

Dear Elektor — just a quick note to thank you for organising such an enjoyable day at Birmingham TIC on Saturday (October 4, 2008, *Ed.*). The college staff were all very friendly, helpful and well able to provide the information to us.
I also enjoyed the food immensely. My only complaint was that the day went too fast!
I look forward to attending similar E-vents when they become available.
**Richard Large (United Kingdom)**

*E-vents covering RFID and High-End Audio Amplifiers are now scheduled, see the Elektor home page for details on the workshops and masterclasses.*

## Cheap 'scopes on review

Dear Editor — I would like to comment the DSO review article which appeared in October 2008 issue of Elektor. I agree with Dr. Scherer's opinion that the Rigol DSO is far superior to the Owon model. I've used my own Rigol DS1062CD at home for a year now and have been very happy with it. I use mainly Tektronix and Agilent DSOs at work. There is a misunderstanding on part of the author about the memory density of the Rigol DSO, all models in the DS1000 series have 1 megabyte of sample memory (512 k per channel if both channels are active, and 512 k for logic analyser). See full specifications from: www.rigolna.com/products_osc_DS1000_spec.aspx.

The logic analyser functions are also good, although serial protocol demodulation and channel naming are not possible like with Agilent mixed signal DSOs. This may change in future firmware releases, they responded to my enquiry. Considering after-sales support, Rigol has a very fast support response from China. I contacted them about a firmware upgrade recently, and got a response & firmware file in a few hours time!

I do not understand the comment on the build quality. I have limited experience on the Owon model but the quality of the Rigol model is good. My own choice was made on the fact that Rigol designed and manufactures the low range Agilent DSO's. If Agilent trusts to rebrand their scopes and sell in their own name then the build quality must be dependable. I would recommend the Rigol's DSOs for general low-frequency laboratory use and with the price tag of less than 1 keuro, one can be fitted on all work tables! It's also an excellent choice for educational institutions, since the students can get experience in real industrial grade instruments. And for any microcontroller work, the logic analyser comes in handy.
**Jussi Säily (Finland)**



The reviewer, Thomas Scherer, replies:

*Dear Dr. Säily, thank you for your comments. Yes, the DSOs from Rigol use 1 MB memory. I mentioned that they can use up to 512 kS per channel.*
*The same about build quality: I never said a word about this. I said that both manufacturers have to improve their products and — looking at the software of the Rigol — in my eyes, there's room for improvement — the software is not good enough.*
*Regarding your other points: I just did not test the logic analyzer functions. And I'm not shure if Agilent just sells rebranded Rigol scopes or if Rigol works just as a hardware factory for Agilent, which would make a difference. I am unable to say what is true.*
**Thomas Scherer (Germany)**

Jussi Säily replies:

I forgot to add one thing about the memory modes. The Rigol DSO has two memory modes selectable from the settings menu. Mine was on the low memory density setting on default (as I suspect was Dr. Scherer's), and I was confused on the low performance before I found out that the high memory density setting needs to be enabled! As you know, engineers don't read manuals ;-)



I didn't mean to upset Thomas, just to clarify some things which may make a difference in selecting the right scope for your personal use. The Rigol DSO has the deepest memory I've seen in any other low price category scope, and is really useful in digital circuit work. They're constantly improving the firmware, and you can easily upgrade it for no charge. The latest firmware I got about a month ago has many improvements like more automatic measurements. Specifically the Agilent DSO3000 series are rebranded Rigol DS5000 series scopes. They're designed and manufactured by Rigol in China.
**Jussi Säily**

## Power LED please

Dear Elektor — first, I've just been reading the September 2008 issue of Elektor, and would like to congratulate the team on yet another great issue. Now, on to the point of this email. I've been thinking for a while that, given the UK government's insistence that all traditional light bulbs be banned within the next three years, there must be a better alternative to the horrible compact fluorescents that are being pushed onto us. Lack of dimming and poor quality make them very undesirable, but as yet I've found no viable alternative to the good old filament bulb.

I've been toying with the idea of direct bulb replacement (bayonet/Edison screw) unit which would consist of a small transformer circuit and suitable LED cluster, capable of direct exchange for a bulb and able to work with the electronic/dimmer switches that many people would otherwise need to replace to use the compact fluorescents.

I could probably come up with a suitable working design, but lack of relevant experience and an even greater lack of free time makes this just another project I'd like to find time to work on :-).

Therefore I thought I'd mention it to yourselves, to see if it might be the sort of thing you would like to investigate and possibly come up with a project for.

Right, thanks very much for the time taken to read this email, and very best wishes to all those who make Elektor the must-read magazine it is.
**Steve Clark (United Kingdom)**

*Thanks for the suggestion Steve, it's been copied into our design lab, as well as to a number of freelance contributors. If readers feel they can contribute in any way, do let us know.*

## Multiple DigiButlers on the same network (2)

Dear Jan — a small error slipped into my previous contribution to Mailbox (November 2008, *Ed.*).

When using a web browser to call a DigiButler not connected to external port 80, it is mandatory to have **http://** in front of the ip address.
**T. Geerts (The Netherlands)**

## DigiButler live demo from France

Our reader Yves Masquelier from France has connected his DigiButler board to the Internet to enable you all to see it's actually working.

His board has been programmed to read a number of temperatures including that of the ColdFire micro!



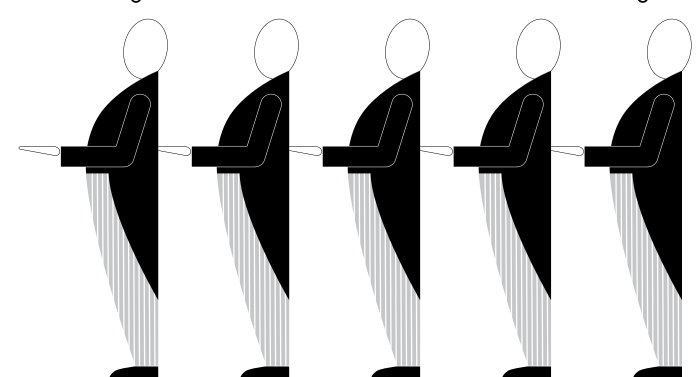

url = http://81.56.186.109:59999
username = user
password = 1234567

Give Yves' DigiButler a call and see if you can bother him to switch the kitchen light on and off! (note: service available subject to Mr Masquelier's provisions)

## Improvements for Luxury LED Bicycle Light

Dear Jan — I'd like to respond to the Luxury LED Bicycle Light article published in the September 2008 issue. Although I liked the article, I consider the author's choice of the driver architecture remarkable to say the least. Elektor has been covering LEDs and LED drivers quite intensively lately and everyone now seems to agree on the current source as the best way to power an LED. All commercially available LED drivers are, in principle, current sources. The driver discussed in the article is a voltage source with pot adjustment. If, after some time, the LED exhibits a change in forward voltage, the current is likely to change, causing the light intensity to fluctuate considerably. Worse, the LED may get excess current causing severe reduction of its lifetime.

The above problems do not occur if you use dedicated LED drivers like the MAX16820 and MAX16832A, which are easy to apply and do not require adjustment. They also allow the compensation network R1-C2 to be dropped, as well as output capacitor C3. See www.maxim-ic.com/MAX16820 and www.maxim-ic.com/MAX16832A.
**Fons Janssen (Maxim Benelux) (The Netherlands)**



## MailBox Terms

- Publication of reader's orrespondence is at the discretion of the Editor.
- Viewpoints expressed by correspondents are not necessarily those of the Editor or Publisher.
- Correspondence may be translated or edited for length, clarity and style.
- When replying to Mailbox correspondence, please quote Issue number.
- Please send your MailBox correspondence to:

editor@elektor.com or
Elektor, The Editor,
1000 Great West Road,
Brentford TW8 9HH, England.




## Graphical Programming of Microcontrollers Using Flowcode

**Saturday 13 December 2008 from 9:00 am to 4.00 pm, Birmingham City University, Technology Innovation Centre.**

*Presenters:*
*Dr. Nick Holden BSc(hons) PhD CEng MIET and*
*Mr. Parmjit Chima BEng PgDip.*

The purpose of this one-day course is to program and apply PIC microcontrollers in an accessible and practical way.
The participants will learn how to use Flowcode to exercise some of the functionality of these modern microcontrollers using peripherals such as timers, counters, digital port I/O, A/D and USART, with polling and interrupt techniques.
The course will use the E-blocks hardware with one of the common 40-pin PIC microcontrollers. The graphical programming of the microcontroller is done with the revolutionary new software Flowcode version 3. The knowledge gained can also be applied to other 8-bit microcontrollers such as the AVR from ATMEL.
The participant will at the end of the day be able to build embedded systems with analogue values and switches as inputs and output via LCD and LEDs.
This workshop is also a very thorough preparation for programming these microcontrollers in C.
Prerequisites include some electronics skills, digital technologies and computer proficiency (Windows).
The course fee is £ 160, including lunch and certificate. Every participant also receives the CD Flowcode software version 3 home edition (value £ 48.30). Elektor subscribers are entitled to a 5% discount.
Be quick to register online at www.elektor.com, there is space for only 16 participants!

## PIC Programming using 'C' - hands-on for beginners

**Saturday 13 December 2008 from 9:00 am to 4.00 pm, Birmingham City University, Technology Innovation Centre.**

*Presenters:*
*Dr. Anthony Wilcox GRIC PhD CEng MIET and*
*Mr Andrew Hill BSc MIET.*

The main goal of this one-day course is to provide an introduction to the programming of PIC microcontrollers in the C programming language. The course is mainly aimed at participants who are unfamiliar with the C programming language, but who would like to learn to use it in an embedded environment.
The participant will be introduced to those aspects of the C language that are most relevant to the programming of microcontrollers. The hardware used in the course consists of E-blocks.
Course objectives: - the participant can make a simple C program - the participant can program a PIC microcontroller in C.
Some experience in programming is recommended, such as (Visual) Basic, Pascal, Assembly or another language. No prior knowledge of C is expected, but some familiarity with electronics, digital technology and computer proficiency (Windows).
The course fee is £ 160, including lunch and certificate. Every participant will also receive free software and example files as presented on the course.
Elektor subscribers are entitled to 5% discount.
Be quick to register online at www.elektor.com, there is space for only 16 participants!

# Elektor comes to the USA

Packed with electronics projects, know-how and technology, Elektor magazine has now come to North America (and Canada)! A special landing page is available for US and Canadian readers. Elektor USA magazine's November 2008 and October 2008 trial issues are on distribution directly when it will be added to the successful English, Dutch, Spanish, French, German, Italian, Portuguese and Brazilian magazines centrally produced by Elektor International Media, with websites to match. Elektor USA issue #1 is scheduled to appear well before Christmas 2008.




from the Publishers' US address after a successful introduction at the Audio Engineering Society (AES) Convention held in San Francisco on October 2-5 and Embedded Systems Conference (ESC) Boston, October 27-30.
The official launch issue of Elektor USA will be **January 2009**

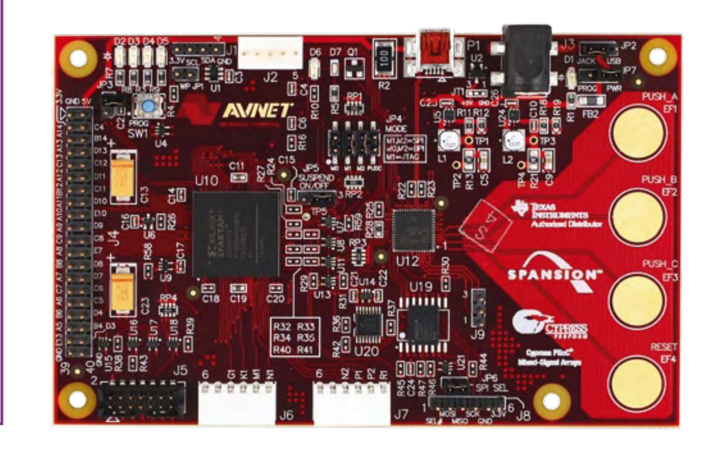
American and Canadian readers originally subscribed to the English-language Elektor can now subscribe on-line using the specially created USA landing page, which contains an offer they will find hard to refuse!

**www.elektor-usa.com**

# Avnet / Cypress Spartan-3A video

Cypress Semiconductor Corp. and the Avnet Electronics Marketing Americas business region of Avnet, Inc. announce the launch of a new online design demonstration "PSoC, the Mixed Signal FPGA Companion Chip." The video shows designers how to use a Cypress PSoC(r) Programmable System-on-Chip in cost-effective companion chip applications with a Xilinx FPGA. The 30-minute video is available on demand and free of charge at the link below.
The new video gives a brief overview of the flexibility and integration of the mixed-signal PSoC device, followed by a detailed review of its FPGA configuration, USB and touch sensing capabilities.

Cypress member of technical staff Dave Van Ess presents these features using the Xilinx Spartan-3A FPGA Evaluation Kit from Avnet,



which pairs a Xilinx low-cost Spartan-3A 400A FPGA with a PSoC device.
The board comes with Cypress's CY3217 (MiniProg) Programmer as part of the Xilinx Spartan-3A FPGA Evaluation Kit, available exclusively from Avnet for $ 39.
For designers interested in a more advanced USB and touch sensing evaluation environment, Cypress offers the CY3214-PSoCEvalUSB Kit, which includes enhanced development and debugging support. The PSoCEValUSB Kit is available on the Cypress Online Store and from authorised distributors.

(080872-I)

**www.cypress.com/go/PR/PSoCFPGAwebinar**
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## DSP Waveform Generator for USB BitScope 100

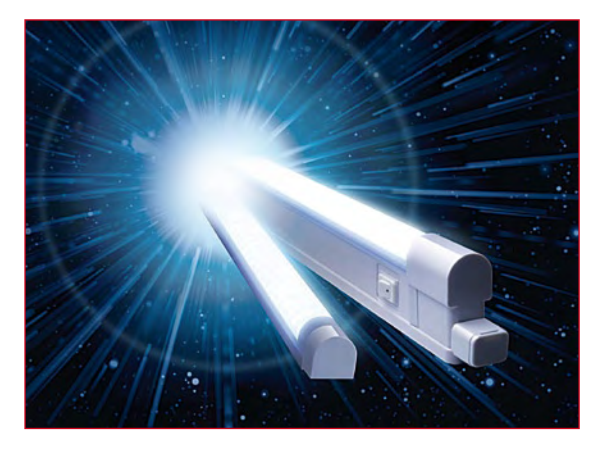
BitGen is a new waveform and timing event generation solution for USB BitScope 100.
It generates standard sinusoid, triangle, sawtooth and square wavefunctions but it is capable of a lot more than this; clocks, voltages, triggers, waveform bursts, sweeps and chirps, white and pink noise, loadable arbitrary waveforms and even live waveforms captured with BitScope can all be generated concurrently with mixed signal acquisition.

Its software selectable synthesisers are controlled using the same powerful DSO program that drives BitScope; there are no new software tools to learn and all generator I/O is integrated with BitScope so setup is fast and easy.
BitGen operates independently or sample locked with BitScope. Triggers are integrated so waveform generation and capture is always perfectly synchronised.
Frequency synthesis is very precise; better than 1 ppm with crystal reference accuracy and event timing and burst duration is also very precise with a resolution better than 50 ns.
A second timing channel accepts external triggers or clocks or it can be used to output synchronised clocks or triggers for external devices. It also serves as a convenient probe calibration signal. BitGen is available now as a purchase option or upgrade pack for USB BitScope 100.

**www.bitscope.com**

(080872-II)

## Ultra-slim, low-power LED strip light reduces energy and maintenance costs



Hawco introduces new linkable, low-profile LED strip lights that offer an economical alternative to incandescent and florescent lighting. Designated PLANETSAVER®, the LED Strip Lights are available in two versions: a 230 volts AC module and a 12 volts DC LED ultras low power (ULP) module. Both versions feature a versatile plug-and-play facility that enables multiple units to be connected in series to meet lighting requirements. The rugged PLANETSAVER LED Strip Lights significantly lower energy consumption and feature a long operating life of more than 50,000 hours, reducing maintenance costs.

The PLANETSAVER instantly light up at full brightness and can be specified to provide either a cold or warm white colour temperature.
Available with a compact straight and/or flexible connection option, up to 10 LED strip lights can be connected in series.
The 230 VAC Led Strip Light is available with lamp dimensions of 320mm to 820 mm, providing a light output of 42 cd to 132 cd.
The 12 V DC LED ULP Strip Light is available in lengths from 320 mm to 820 mm with corresponding light output of 48 cd to 138 cd.
Typical applications include refrigeration, chiller cabinets, kitchen units, shop displays, under shelves, pelmits, bookcases and wardrobe.

**www.hawco.co.uk**

(080872-III)

## 13.56 MHz RFID Reference Design

Atmel® Corporation announced its Keen+ reference design for the development of secure, 13.56 MHz logic-based, passive RFID, close proximity applications.
The AT88SC-ADK2 Keen+ development kit includes Atmel's Crypto Evaluation Studio tool suite, an application development board, CryptoRF® samples in both tag and smart card form, a USB cable, and a quick start guide.
The Crypto Evaluation Studio tool suite has a menu-driven, graphical user interface for CryptoRF configuration and testing, plus development libraries and code examples for host-side cryptographic operations required for secure communication. The application development board includes Atmel's ISO/IEC 14443-B-compliant, AT88RF1354 host-reader chip; an Atmel AVR flash microcontroller; and USB connectivity to PC and power. Schematics and PCB layout are also included.
The AT88RF1354 host reader performs RF communication, packet formatting, decoding, and communication error checking and is based on the royalty-free, ISO/IEC

14443-2 Type B signal modulation scheme and ISO/IEC 14443-3 Type B frame format, used by 60% of the vendors of RFID host readers. Data is exchanged half duplex at a 106 kbit per second rate. A two-byte CRC_B provides communication error detection capability. The AT88RF1354 can be used with both RFID transponders or contactless smart cards and is compatible with 3.3 V and 5 V host microcontrollers with two-wire or SPI serial interfaces.

The highly integrated reader IC requires fewer external components than competing RFID reader chips, resulting in a BOM in the $2.00 range for a host reader based on this reference design. This is significantly lower than designs using competing RFID reader ICs.




The AT88RF1354 is available in the smallest package option obtainable today - a 6mm × 6mm, 36-pin QFN.

Atmel's Keen+ RFID Development Kit, including reference designs and software is available now for $99.95.

**www.atmel.com/products/secureRF/**

(080872-IV)

# LED Module Strips for signage and channel-letter applications




Providing solid state lighting design engineers with a flexible and scalable lighting solution, TT electronics OPTEK Technology has developed a series of LED module strips for signage and channel-letter applications. Available in red, amber, green, blue and white, the LED strips provide fast response times and low power consumption, resulting in low power requirements from circuit power supplies. Typical applications for OPTEK's LED light strip product line include commercial channel lighting for signage applications, media illumination, large area backlighting, point-of-sale displays, mood-setting decoration, landscape lighting, and neon replacement lighting.

The LED module strips include the following models:

--OVM12F3x7 Series 3 LED module strips - comprised of 30 modules per strip in lengths of 3 inches to over 40 feet long, the waterproof strips feature a power dissipation of 1.5 W, input voltage of 12 V, and operating temperature ranging from –30°C to +50°C;

- OVM18F4x7 4 LED module strips - consisting of 20 modules per strip in lengths from 3 inches to over 30 feet long, the waterproof strips feature a power dissipation of 1.5 W, input voltage of 18V, and operating temperature ranging from –30°C to +50°C;

- OVQ12S30x7 flexible LED light strips - comprised of 30 high brightness LEDS per unit in lengths up to 16 feet, the red and yellow LED strips feature a power dissipation of 2.7 W while the green, blue, white and warm white strips feature a power dissipation of 2.3 W, with an input voltage of 12 V and operating temperature of –30°C to +50°C.

**www.optekinc.com/viewparts.aspx?categoryID=51**

In Europe, contact JP Delaporte at **info@optek-europe.com.**

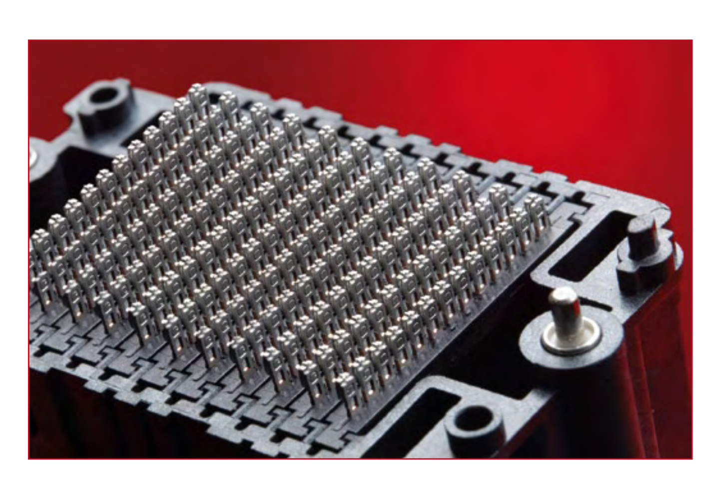
In Asia, contact T.H. Swee at **thswee@optekasia.com**

(080872-V)

# Molex: new solder charge technology

Molex Incorporated has developed a new Surface Mount Technology (SMT) attach method that offers better fatigue strength and lower applied costs compared to traditional SMT mounting methods. Already Molex's new Solder Charge Technology™ has been adopted by major OEMs and CEMs to enhance yields and increase reliability over typical Ball Grid Array (BGA) attach methods.

The solder-charge uses standard reflow processing and a reflow profile is available for every product that takes advantage of this high-density feature. The solder-charge extends slightly beyond the tip of the terminal to seat within the solder paste on the solder-pad. The terminals lower onto the pad upon the melting of the solder mass within the reflow oven. In reflow, the solder transforms into a rectangular sloping solder fillet.



This bugle-shaped solder-charge fillet is a far more robust structure than a ball-shaped BGA solder fillet. In addition, the solder not only provides a 360 degree coating around the terminal but also reaches through the hole in the pin for added retention strength.
Incorporating Solder Charge Technology™ into the design process offers several benefits over standard BGA attachments. The solder-charge provides a significant amount of tolerance to compensate for variability in the PCB flatness, giving added assurance that the PCB adhesion will work effectively. In-house tests have shown the resulting solder-charge joint is three-times stronger than that of a BGA. The mechanical design of the joint allows for visual inspection post processing, this reduces the process engineer's reliance on Dage x-ray screening. Overall, the shorter cycle times and fewer rework and secondary processing steps help increase output providing a very cost-effective solution.
Ideal for high-speed circuitry, Molex Solder Charge Technology™ achieves a reliable mating interface with 2.00 mm wipe and two points of contact for clean signal transmission and enhanced durability.
For information about incorporating this attachment style into an assembly design, visit the url below.

**www.molex.com/product/soldercharge.html**

(080872-VIII)

# CyFi: world's most reliable 2.4-GHz low-power wireless solution for embedded control applications

Cypress Semiconductor Corp. recently introduced a complete 2.4-GHz solution for the wireless embedded control market. The new CyFi™ wireless solution delivers the industry's leading combination of reliable connectivity, power-efficiency and superior long range, and is supported by the flexible and easy-to-use design capabilities of Cypress's flagship PSoC® programmable system-on-chip. The solution is optimized for applications requiring sensors, actuators, active RFIDs, standard cable replacement, and human-to-machine interfaces. Prime applications for this solution include wireless sensor networks, home and building automation and remote controls for a broad range of markets such as industrial and consumer.

CyFi transceivers are powered by PSoC devices, which integrate programmable analogue and digital blocks, hundreds of pre-configured user modules and an 8-bit microcontroller onto a single chip. A PSoC device can replace multiple discrete components, integrates numerous functions and can be reprogrammed at any stage of the development process for unmatched flexibility. The CyFi protocol stack links the PSoC device and the CyFi transceiver, and offers a pre-configured, customizable PSoC firmware module that can be dropped into the PSoC Designer™ 5.0 integrated development environment (IDE). The combined solution enables designers to create feature-rich wireless applications with no complex coding.

For more information on the CyFi Low-Power RF solution, visit the website below.
Cypress further introduced the CY3271 PSoC FirstTouch™ Starter Kit with CyFi Low-Power RF, the CY3271-EXP1 Environmental Sensing Expansion Kit, the CY3271-RFBOARD RF Expansion Kit and the CyFi Low-Power RF Development Kit (CY3210-CYFI).




The CY3271 USB thumbdrive kit provides an easy way to evaluate the quick prototyping and debugging of wireless systems based on the CyFi solution. Designers can also use the kit to leverage the touch-sensing, temperature-sensing, lighting-sensing and proximity sensing capabilities of PSoC devices. The CY3271 kit includes PSoC IDE software, a sense and control dashboard for data collection, a PC dongle with RF, a multifunction board, an RF expansion board with power amplifiers for long-range wireless applications, and two battery boards.
The CY3271-EXP1 Environmental Sensing Kit is the first of many future expansion kits to the CY3271 that enables customers to quickly and easily evaluate the robust, programmable analogue capability of a PSoC device, plus CyFi Low-Power RF — quickly enabling a wireless sensor solution with pressure, humidity, temperature and ambient light sensors.

The CY3271-RFBOARD RF Expansion Kit is an add-on to the CY3271 that provides two additional RF expansion and AAA battery boards — further enabling evaluation of the CyFi Low-Power RF solution.

The CY3210-CYFI general-purpose development kit enables seamless prototyping and debugging of PSoC devices and CyFi transceivers. The kit includes two development boards, two PSoC modules and three CyFi modules to build wireless applications.
The CYRF7936 CyFi transceiver is now available in a 40-pin QFN package. The CY3271 PSoC FirstTouch Starter Kit, CY3271-EXP1 Environmental Sensing Kit, CY3271-RFBOARD RF Expansion Kit with CyFi Technology and the CyFi Development Kit (CY3210-CYFI) are currently available on the Cypress Online Store as well as in channel partners' inventories.

**www.cypress.com/go/PR/CyFi**
**www.cypress.com/shop**

(080872-X)



## Unicycle-riding robot

Murata Manufacturing Co., Ltd. has developed a unicycle-riding robot, called MURATA GIRL™, following its bicycle-riding robot MURATA BOY™.

Various types of robot capable of performing such roles as entertainment and security have been created recently for use in our daily lives. These robots require several of Murata's own products, including capacitors that store electricity in electronic circuits, sensors that control motion, and communication modules that exchange information. Since the robotics market is expected to experience strong growth, expansion in the demand for such electronic components is also expected.

MURATA GIRL can maintain balance and move around on a unicycle, keep a certain distance from an object using a US sensor, and transmit moving images via a live camera.

Signals from the gyro sensors help control the unicycle wheel in the forward and backward directions and a fly wheel inside her torso monitors side direction in order to maintain balance.

Ultrasonic sensors detect obstacles (send/receive pair of sensors), allowing the robot to judge how far away an obstacle is by measuring the time it takes to transmit ultrasound and receive the reflected signal from the obstacle.
MURATA GIRL™ sends and receives commands and data via mobile information terminals and PCs using a 2.45GHz band Bluetooth radio wave.

**www.murataboy.com/ssk-3/index.html**

(080872-VI)

## Freescale: world's most powerful automotive microcontroller for 'green' engine design

Faced with soaring fuel prices and pressures to curb greenhouse gases, automakers are racing to design vehicles that deliver better fuel economy and reduced emissions. High-performance microcontrollers (MCUs) play a key role in green automotive design, and Freescale Semiconductor has introduced the industry's most powerful and sophisticated MCU for engine control in mainstream, high-volume automobiles.
Freescale's new MPC5674F is the latest addition to the company's growing portfolio of 32-bit automotive MCUs built on Power Architecture™ technology. The MPC5674F addresses the automotive industry's need for precise control of engine events, enabling developers to optimize combustion and tune engines for improved fuel efficiency and cleaner emissions, without sacrificing performance.
Manufactured on 90-nanometer technology, the MPC5674F outpaces other powertrain MCUs with its 264 MHz clock speed. This fast performance allows the core to execute more than 600 million Dhrystone instructions per second (DMIPS) – about 10 times the performance level of today's conventional engine controllers. The MPC5674F MCU's combination of exceptional CPU performance, advanced signal processing capabilities, quadruple analog-to-digital converters (ADCs) and 4 MB on-chip flash memory addresses the growing computational demands of green engine designs. These designs include common rail diesel injection systems, gasoline direct injection engines, homogenous charge compression ignition (HCCI) systems and hybrid electric vehicles (HEVs).
The MPC5647F helps automotive developers meet government-mandated emissions standards by providing 4 MB of flash – one of the largest flash arrays available in the powertrain MCU market. This large amount of on-chip flash provides ample non-volatile memory to support computationally intensive modeling environments and auto code generation, without the cost and complexity of adding off-chip memory.

(080872-IX)



# LED Top with Special

## Spin the top to display programmed text

Michael Bragard (Germany)

**If you fit a line of LEDs on a circular PCB and power them on continuously, they generate rings of light when the board is spun. If you add a microcontroller, you can use the same set of LEDs to obtain a more interesting effect by generating a 'virtual' text display. This article also describes a simple technique for using the Earth's magnetic field to generate a synchronisation pulse. The potential applications extend from rotation counters to an electronic compass.**

Do you still remember your secondary-school physics classes? Some students found them very relaxing, while others (which presumably includes many of our readers) probably recall the following situation: a free-hanging loop of wire is suspended in the magnetic field of a horseshoe magnet. The teacher causes a DC current to flow briefly through the loop of wire, and it moves to one side and then back as though pushed by an invisible hand. The teacher then tells you that the operating principle of the electric motor is based on this phenomenon.

After you had more or less accepted this remarkable fact, the next physics class brought yet another surprise: the teacher said that the effect also worked in the opposite direction. This time, he connected a sensitive moving-coil meter to the loop of wire instead of a current source as before, and then he moved the loop back and forth in the magnetic field. Each movement of the loop caused a deflection of the meter pointer. He concluded this lesson with the words, 'This is the operating principle of an electrical generator'.

Now you may be wondering what this would-be generator has to do with our LED top. Let's briefly recall another version of the above scene: a coil is rotated between the arms of a horseshoe magnet, and at the same time a sinusoidal trace appears on the screen of an oscilloscope connected to the coil.

The top described here includes a small coil, which is located in the Earth's magnetic field instead of the field of a horseshoe magnet. To put it more precisely: when the top spins, the coil rotates in the horizontal component of the Earth's magnetic field. If the speed of rotation is constant, the voltage induced in the coil is sinusoidal – in other words, the coil acts as an electrical generator. Of course, the Earth's magnetic field is very weak; the horizontal component used here has a strength of less than 20 $\mu$T in Central Europe. The generated voltage is proportional to the enclosed area of the coil and the number of turns. There are upper limits to both of these quantities, since the coil must fit in a top that can be spun by hand. To avoid the effort of making a hand-wound coil, here we use a commercial fixed inductor. Naturally, the amplitude of the voltage is also proportional to the speed of rotation, and thus to the skill of the user.

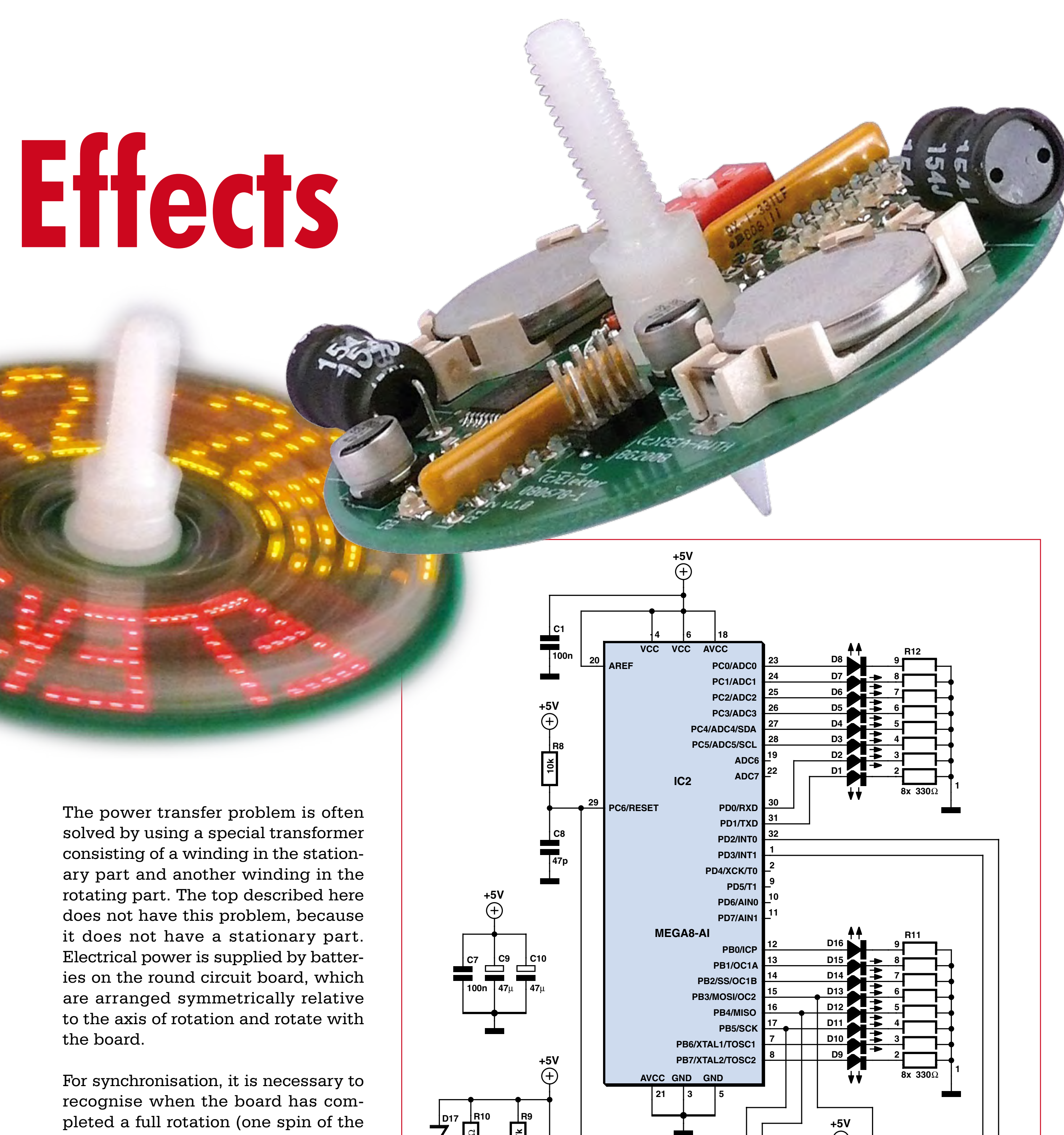
The coil voltage that is needed for this application is on the order of 50 $\mu$V.

### Concept

Moving LEDs driven by rapidly changing signals have become relatively popular in recent years. *Elektor* has also published construction articles for devices with rotating LEDs that can display a virtual text or pattern in space [1]. They operate on the same principle as a raster-scan monitor. The LEDs move over a surface in space in the same way that an electron beam moves over the phosphorescent screen of a CRT. Both systems owe their operation to the latency of human visual perception. The persistence of the individual picture elements and their constant fast repetition produce the illusion of a coherent, stable image.

Most systems with rotating LEDs are standard products. They must overcome two problems that are inherently associated with the principle. The first problem is transferring electrical power to the rotating part, while the second problem is generating a suitable synchronisation signal.

# Effects




The power transfer problem is often solved by using a special transformer consisting of a winding in the stationary part and another winding in the rotating part. The top described here does not have this problem, because it does not have a stationary part. Electrical power is supplied by batteries on the round circuit board, which are arranged symmetrically relative to the axis of rotation and rotate with the board.

For synchronisation, it is necessary to recognise when the board has completed a full rotation (one spin of the top). This is essential if the objective is to display a stationary image. In the commonly used designs with a stationary part, an IR light beam or a Hall sensor is used to generate a pulse once per rotation. This solution is very exact and easy to construct, but generating a synchronisation pulse is much more difficult with a top that does not have a stationary external reference point. Costly acceleration sensors or angular

**Figure 1.**
**The circuit of the LED top essentially consists of an Atmel ATmega8 microcontroller linked to an opamp circuit that generates the synchronisation signal.**

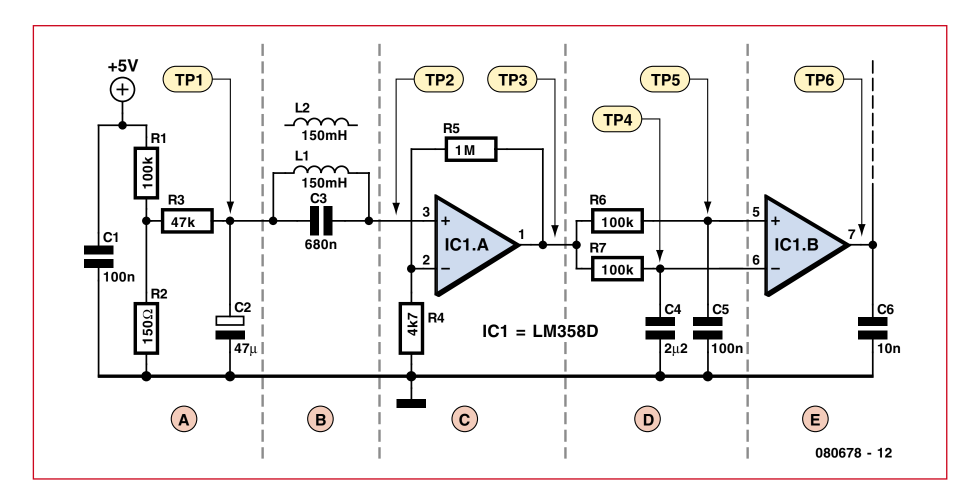



Figure 2. For the sake of clarity, the analogue portion of the circuit is shown separately here, divided into five functional parts (A to E). The signals shown in Figures 3 to 5 were measured at the test points marked in this diagram (TP1 to TP6).

velocity sensors are also of no use here. As previously mentioned, the sensor used with this top is a small, inexpensive inductor spinning in a local, homogeneous magnetic field. For example, the magnetic field could be the Earth's magnetic field.

The top will also work just as well if you hold a permanent magnet next to it. With appropriate amplification and phase comparison of phase-offset signals, a square-wave signal suitable for triggering a microcontroller interrupt can be generated from the small, induced sinusoidal voltage.

## Circuit

The schematic diagram of the LED top (**Figure 1**) essentially consists of an Atmel ATmega8 microcontroller linked to an analogue circuit that generates the synchronisation signal. The microcontroller (IC2) drives two LED strips, each with eight SMD LEDs. The LED currents are limited by resistance networks. The rest of the digital portion of the circuit corresponds to the usual minimum configuration of an Atmel AVR microcontroller, with a power-on reset network (R8/C8) and an ISP connector (K3), which can be used to load the software into the microcontroller. Capacitor C1 is intended to decouple HF interference from the analogue portion.

The power supply of the circuit has been kept very simple. The two CR2032 cells wired in series provide a nominal voltage of 6 V. The combination of R10 and D17 (a 5.1-V Zener diode) limits this to a value that the microcontroller can handle. Battery utilisation is fairly good, since the circuit will continues to operate until the microcontroller stops running at around 3 V. The supply voltage is buffered by the parallel combination of C9 and C10, which provide a capacitance of around 100 μF. This is divided between two capacitors to maintain a balanced weight distribution on the rotating PCB.

For the sake of clarity, the analogue portion of the circuit is shown separately in **Figure 2**, divided into five functional parts (A to E). Part A supplies the left lead of inductor L1 (at TP1) with a constant voltage of 7.5 mV via R3 and buffer capacitor C3. This voltage is produced by a voltage divider with

## Listing

**Main algorithm for rotation detection in the LED top**

```
ISR (INT0_vect)
{
   // rising edge of the sensor pulse
   current_round_time = current_round_time_zaehl;

   // counts the duration of the last round in ms
   // is starting a new round realistic?
   (80% of the time of the last round)
   if (current_column > (column_number*8)/10) {
       // here: adopt lap time for new co-
   lumn timing, Timer1 runs with 1MHz
       timer1_startvalue =
   1000/column_number*current_round_time;
       current_column = 0;
#ifdef ROTATION_COUNTER
       if (game_status == GAME_ONGOING)
              number_of_turns++;
#endif // ROTATION_COUNTER
   }

   // clear elapsed time meter for the
   time in ms between two rising edges
   current_round_time_zaehl = 0;
}

ISR (TIMER0_OVF_vect)
{
   // this routine should be cal-
   led every millisecond
   TCNT0 = 255 - 125;

   // increment the cyclic coun-
   ter (without overflow)
   if (current_round_time_zaehl < 255) {
       current_round_time_zaehl++;
   } else {
       current_round_time_zaehl = 255;
   }
}

ISR (TIMER1_OVF_vect)
{
   // calling time is based upon the actual speed
   TCNT1H = 255 - (timer1_startvalue >> 8);

   TCNT1L = 255 - (timer1_startvalue & 255);

   // next column, or missed syn-
   chronization condition,
   // then new start: time-controlled
   if (current_column < column_number) {
       current_column++;
   } else {
       current_column--;
   }
}
```

its associated decoupling capacitor. Part B has another decoupling capacitor and the sensor coil L1, in which the voltage is induced. With typical coil characteristics, rotation in the Earth's magnetic field generates an induced sinusoidal voltage with an amplitude of around 50 $\mu$V. The induced 50-$\mu$V AC voltage is present at TP2, superimposed on the 7.5-mV DC voltage (see **Figure 3**). Inductor L2 is not connected to the circuit; it is only present on the board for balancing.

The third part (C) of the analogue portion contains opamp IC1a, which is configured with R4 and R5 as a non-inverting amplifier with a voltage gain of 200. This yields a sinusoidal voltage with an amplitude of 10 mV at the output of the opamp (LM358 pin 1, or TP3), superimposed on a DC voltage of 1.5 V (**Figure 4**). This voltage forms the input signal of part D of the circuit, which consists of two passive low-pass filters (R6/C5 and R7/C4). In addition to attenuating HF interference, which is unavoidably present when the top is used close to a source of electromagnetic interference such as a PC, the differing time constants of these filters (C4 is much larger than C5) produce a phase offset between the filter outputs at TP4 and TP5. This can be seen graphically in **Figure 5**.

These two sinusoidal signals are fed to the inputs of IC1b (pins 5 and 6) in part E. This opamp does not have any feedback, so it operates as a comparator with its full open-loop gain and compares the two phase-offset sinusoidal signals on its inputs (which have nearly the same amplitude). This comparison causes the opamp's output to be High when the voltage on the non-inverting input of the opamp (TP5) is higher than the voltage on the inverting input (TP4). This is the case for half of the sine-wave period, and thus for half of the top rotation. The output of this opamp is fed directly to the interrupt input of the ATmega8 (IC2), where each rising edge indicates the start of a new rotation.

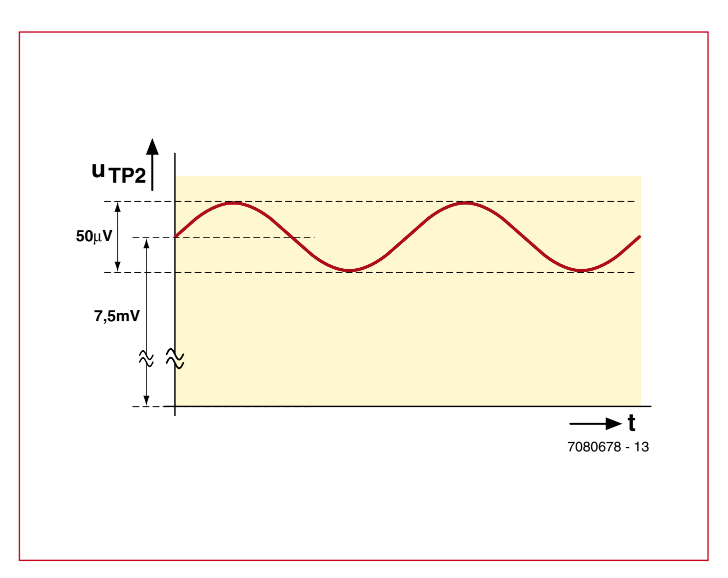



Figure 3. The signal voltage induced in inductor L1 by the Earth's magnetic field is only around 50 $\mu$V.

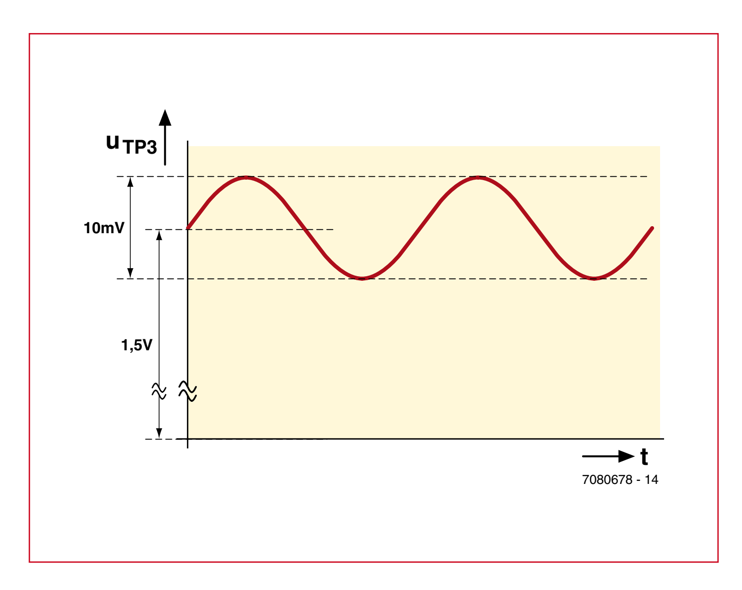



Figure 4. The signal after amplification by opamp IC1a.

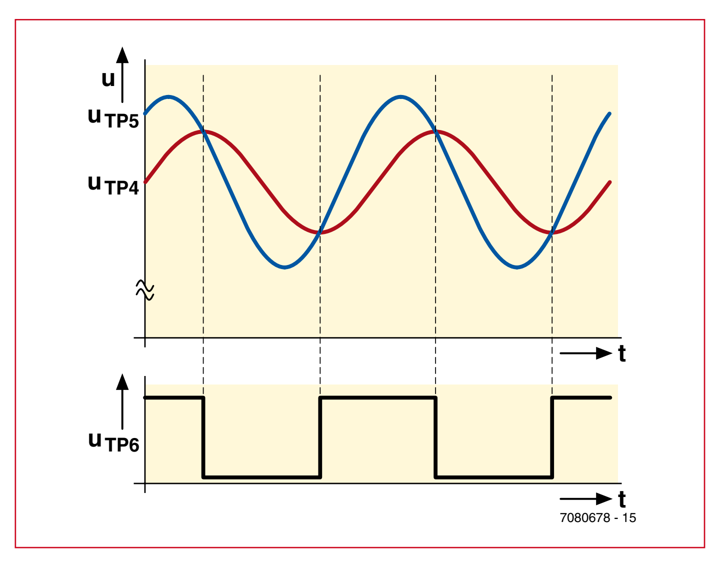



Figure 5. Comparator IC1b generates a pulse signal from the phase-shifted outputs of the RC networks. The pulse signal drives the interrupt input of the microcontroller

## Assembly

Fitting the components on the circular PCB (**Figure 6** and **Figure 7**) is very easy if you use the parts kit available from the Elektor Shop. This is because all the SMD components are pre-assembled, so you only have to solder the leaded components to the board. You can adjust the weight balance of the components on the board by slightly shifting the positions of the leaded components, in order to obtain the least amount of wobble when the top spins.

If you want to assemble your own board from scratch, pay careful attention to the polarity of the SMD LEDs. Study the data sheet closely, and if necessary test the LEDs with a 9-V battery and a 1 kΩ series resistor. Of course, proper orientation is important for all components that have a specific orientation.

For the axle of the top, we used two plastic (polyamide) M6 screws with good results. We glued the heads of the screws together to form an axle, and then fitted the PCB of the top to the lower screw between two washers and secured with a nut. It's a good idea to use a normal pencil sharpener to put a point on the lower plastic screw in order to reduce friction so the top will spin longer.

## Software

The software for the LED top was written in AVR Studio [2], which is available from Atmel for free download via

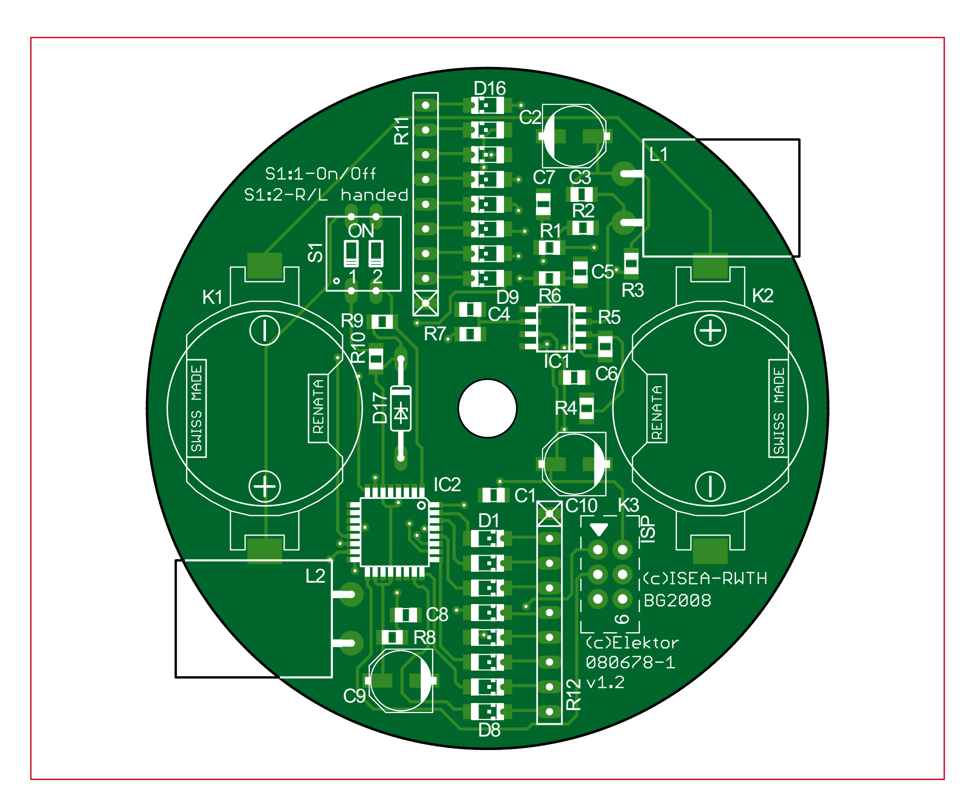



Figure 6. The circular PCB for the top is available with the SMDs pre-assembled.

the Internet. The C code was compiled using the GCC cross-compiler. The code can be loaded into the ATmega8 via the ISP connector on the PCB. Operation of the code is essentially interrupt-driven. After the initialisation and generation of the display matrix, the main routine constantly tests whether the running condition is still satisfied. It is satisfied if the duration of one rotation falls within certain range, which can be configured using constants. The core algorithm for the detection of a complete rotation is described briefly below. It is also shown in the listing, and it comprises three interrupt handlers that service the external interrupt and two timer interrupts. The rest of the program should be self-explanatory and adequately commented.

The hardware interrupt routine becomes active when a rising edge is detected on the INT0 pin. After this interrupt is triggered, the ISR(INT0_vect) routine first checks whether the time of the last rotation is plausible. The start of a new rotation is only plausible if the duration of the previous rotation is at least 80% of the time of the new rotation. Next, the exact time for a new column is determined from Timer1, which runs at 1 MHz.

This time must be adjusted constantly because the top spins slower and slower while the program is running, so the columns must be displayed for a slightly longer time on each rotation. The variable current_column is set to zero, which causes the image to be built up again from the first column of the display matrix. The variable current_round_time_zaehl uses Timer0 to count the time between two rising edges for the purpose of plausibility checking, and it is also reset to zero here. The timer interrupt routine ISR(Timer0_OVF_vect) is called every millisecond under time control, and it increments (without overflow) the counter for the duration of the current rotation (current_round_time_zaehl).

Timer1 and its routine ISR(Timer1_OVR_vect) are used to increment the columns in the display matrix. This timer is first updated with the time to the next call (which means the distance between the two columns) by adjusting it according to the current rotation speed of the top as determined for the last rotation. If the synchronisation pulse is missing, which means that the external interrupt does not occur at approximately the expected time, a new rotation can be started here under purely time-based control. However, practical experiments have shown that this is not necessary, so all this does is to prevent an overflow of the variable current_column.

The full source code is available on the project page for this article at www.elektor.com for free download. After downloading the source code, you can easily modify the text to be displayed, which is contained in a string in the

## COMPONENTS LIST

**Resistors**

All SMD 0805, 1 %, unless otherwise indicated
R1,R6,R7 = 100kΩ
R2 = 150Ω
R3,R9 = 47kΩ
R4 = 4kΩ7
R5 = 1MΩ
R8 = 10kΩ
R10 = 22kΩ
R11,R12 = 330Ω 9-pin SIL resistor array

**Capacitors**

C1,C5,C7 = 100nF (SMD 0805)
C2,C9,C10 = 47µF 16V (SMD electrolytic)
C3 = 680nF (SMD 0805)
C4 = 2µF2 16V (SMD 0805)
C6 = 10nF (SMD 0805)
C8 = 47pF (SMD 0805, NP0)

**Inductors**

L1,L2 = 150mH fixed inductor, $Q_{min}$ = 50, RM5 (12x16 mm), e.g. Fastron 11P-154J-50 (Reichelt.de # L-11P 150M)

**Semiconductors**

D1-D8 = LED, red, 628nm, SMD 1206 with lens, e.g. Kingbright KPTD-3216SURC (Reichelt.de # 1206K RT)
D9-D16 = LED, yellow, 588 nm, SMD 1206 with lens, e.g.. Kingbright KPTD-3216SYC (Reichelt.de # 1206K GE)
D17 = zener diode 5.1V 1.3 W (BZV85-C5V1)
IC1 = LM358 (SMD SO8)
IC2 = ATmega8-16AU (Atmel), SMD TQFP-32

**Miscellaneous**

S1 = DIP switch 2-way (MULTICOMP MCDS02, DIL04)
K1, K2 = CR2032 SMD battery holder (Renata SMTU-2032-1-LF, SMTU-2032-1, Reichelt.de # KZH 20PCB-1)
K3 = 6-way DIL pinheader, lead pitch 2.54mm (Tyco-AMP # 1241050-3 AMP)
Polyamide screw, M6x20 with nut and 2 washers
BAT1, BAT2 = Lithium button cell type CR2032
Kit of parts incl. SMD-populated board, Elektor SHOP # **071120-71**

header. After this, compile the entire source code with the widely used GCC compiler and load it in the top via the ISP port. Leave the fuse bits in the ATmega8 set to their factory default values (1 MHz internal clock). The microcontroller in the parts kit available from the Elektor Shop is pre-programmed, so the top is ready to use immediately after assembly and will display a demo text. However, you can replace the program code at any time with newly compiled code containing your own text.

## Applications

Of course, you are free to choose the text to be displayed by the top – anything from 'Hello World' to a company name or a short slogan is possible. With 'Happy Birthday' plus the name of the recipient, the top makes an ideal personalised birthday gift. You can also extend this idea to the pre-Christmas season.

By programming an additional timer in the ATmega code, you could implement a sort of miniature Advent calendar. For example, the top could display a nice phrase or the keyword for a little surprise on each day of Advent. A software version with a rotation counter has also been developed to cause the top to generate a 'live' display of the number of rotations it has completed. You could then organise a competition to see who is the best top spinner (such a competition was staged live at the Elektronika show in Munich last November). At the time of publication of this article, several tops with this software will in action in the Elektor booth at the electronics trade show in Munich, where they form the basis for a sporting competition. Several hundred rotations can certainly be achieved, and the daily champion among the top spinners will receive a prize – a LED top, of course!

Storing the results in an internal EEPROM is another conceivable extension. In addition to the number of rotations, it would also be possible to display the angular velocity or other derived quantities. Another effect that illustrates the basic principle of the circuit can be achieved by displaying the letters 'WSEN' with a space between each pair of letters.

Figure 7. Top view of the spinning-top PCB. Only one of the two inductors is used in the circuit. The second one is only present for mass balance.

This gives you a sort of compass that shows the observer the orientation of the currently dominant magnetic field. Although there may be devices that are simpler and more suitable for showing compass directions on a desert expedition, they certainly do not create the same sense of marvel as our spinning top compass.

## Conclusion

When Michael Faraday investigated the basic principles of induction in 1831, he presumably did not envisage that one day they would be applied to an LED top. Your secondary-school physics teacher was probably equally unsuspecting. The top was developed for students in a hands-on group at the Institute for Power Electronics and Electrical Drives of RTWH Aachen, Germany [3], with the aim of offering first-semester students a circuit that even electronics neophytes could assemble and whose operation they could understand. In addition, the circuit had to be suitable for taking home after being assembled and being used there without elaborate equipment (power supply, soldering iron or PC) to display a function that everyone could understand. If in addition the theoretical contents of the lectures (including the principle of induction, non-inverting operational amplifiers, and C programming) can be incorporated in a pocket-sized project, experience from past semesters shows that this often creates enthusiasm and generates interest in learning even more.

(080678-1)

## Links and references


[1] 'Rotating Message Display with LEDs and an AVR Micro', Steffen Sorge, Elektor January 2007.

[2] AVR Studio: www.atmel.com/avrstudio

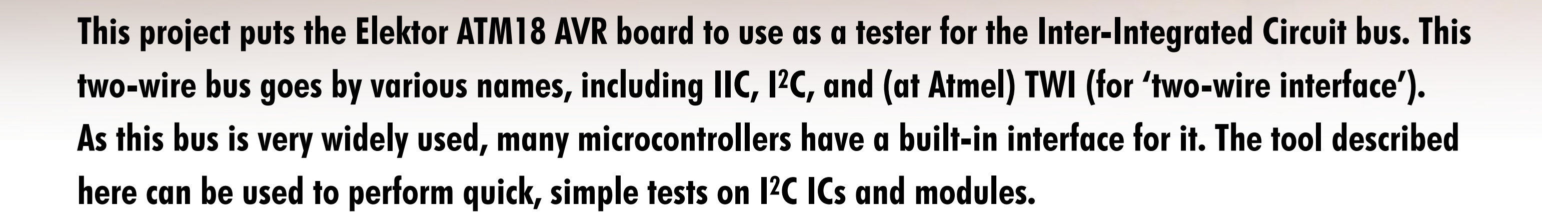
[3] ISEA: www.isea.rwth-aachen.de/en



# Bits on Parade

## An I²C bus tester

Udo Jürsz and Wolfgang Rudolph (Germany)



**This project puts the Elektor ATM18 AVR board to use as a tester for the Inter-Integrated Circuit bus. This two-wire bus goes by various names, including IIC, I²C, and (at Atmel) TWI (for 'two-wire interface'). As this bus is very widely used, many microcontrollers have a built-in interface for it. The tool described here can be used to perform quick, simple tests on I²C ICs and modules.**

When engineers at Philips developed the I²C bus 20 years ago, they probably didn't have any idea how widespread and important it would become. Nowadays it forms an essential part of many types of diagnostic and control systems and other products. It is also used in most embedded applications. The reasons for this success are readily apparent: with a data transmission rate of up to 3.4 Mbit/s and low cost, it is an attractive option. It was designed right from the start to enable networking of multiple components. As a bidirectional bus with a master/slave architecture, the I²C bus does a very good job of fulfilling this task.

Although its software addressing scheme and integrated protocol may make it appear complex and cumbersome at first, it is easy to use in practice. Its two signal lines, consisting of a serial clock line (SCL) and a serial data line (SDA), can be used to control a large number of sensors or implement communication tasks between microcontrollers. The original data transfer rate was 100 kbit/s, but in 1992 it was increased by a factor of 4, and 1998 it was boosted to a healthy 3.4 Mbit/s. Its 'clock stretching' capability also allows the bus to be used to service very slow bus devices. With the latest developments, it is now possible to control well over 30 devices on each bus segment.

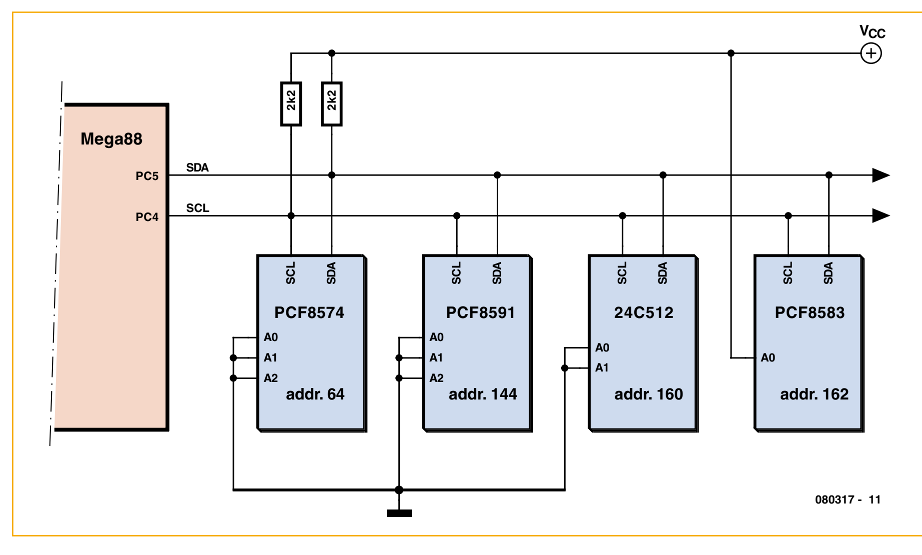



Figure 1. I²C bus with four slaves.

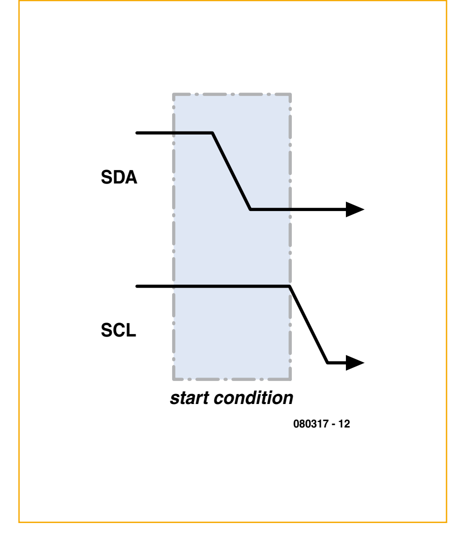
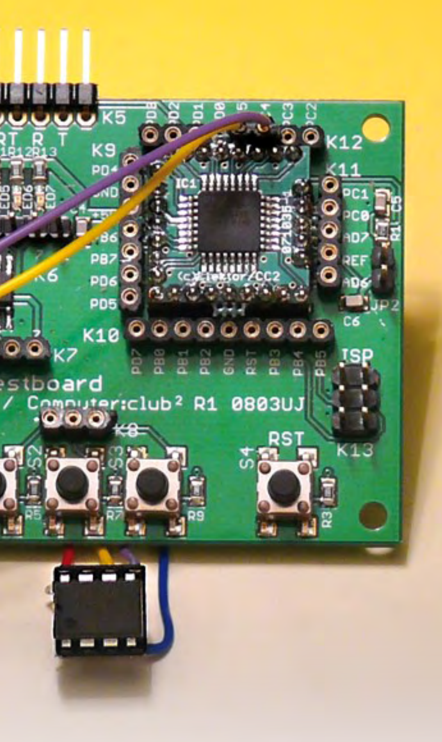



Figure 2. Start condition: SDA goes low while SCL is high.



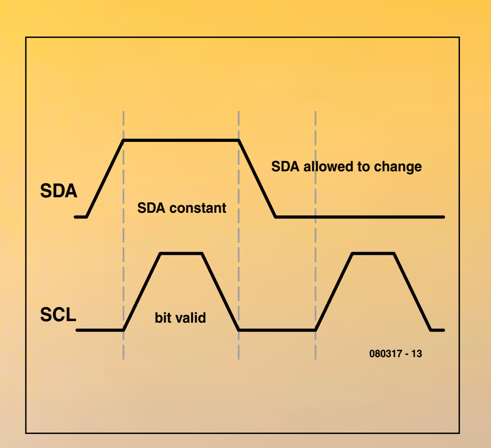



**Figure 3. Each data bit is transferred when the signal on the clock line (SCL) indicates that the data is valid.**

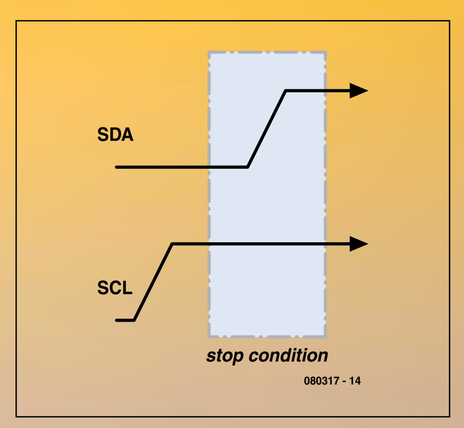



**Figure 4. Stop condition: SDA goes high while SCL is high.**

## Protocol

Data is transmitted in both directions on the bus. To enable access to individual target devices, each I²C bus IC has its own address. The I²C bus protocol has a set of precisely defined situations that allow each bus device (slave) to recognise the start and end of a transmission and whether it is being addressed by the master device (microcontroller). Both lines (SDA and SCL) are high in the quiescent state and thus inactive.

**Start condition**
The start condition indicates to the devices on the bus that a data transmission will follow. The start condition is generated by changing the state of the SDA line from high to low while SCL is high (**Figure 1**).

**Data transmission**
The currently active transmitter places eight data bits on the data line (SDA), which are shifted serially by the clock signal pulses on the SCL line generated by the master (**Figure 3**). The data transfer starts with the most significant bit.

**Acknowledge**
The currently active receiver acknowledges the receipt of a byte pulling the SDA line low while the master generates the ninth clock pulse on the SCL line. This means that SDA goes low during the ninth clock pulse on the SCL line. The acknowledgement also means that the receiver expects to receive another byte. If the receiver wishes to end the transmission, it must indicate this by omitting the acknowledgement. The actual end of the transmission is achieved by generating the stop condition.

**Stop condition**
The stop condition is the reverse of the start condition with regard to the level on the SDA line. In this case, SDA must change from low to high while SCL is high (**Figure 4**). This ends the data transmission.

Addresses are transmitted and acknowledged in exactly the same way as data. The following process occurs in the simplest case, which is a data transfer from the master to a slave (such as a PCF8574 output port). First, the master generates a start condition and then transmits the address of the port IC in bits 7–1, with the desired data transmission direction set in bit 0 (in this case ‘0’ for ‘write’). The address is acknowledged by the addressed slave device. The master then sends a data byte, which is also acknowledged. It can break the connection now by generating a stop condition, or it can send additional data bytes to the same slave device.
This is all we want to say here about the basic operation of the I²C bus. There are many other interesting things about the bus that could be described, such as using several masters on a single bus, reserving the bus (repeat start condition), byte transfers and acknowledgement. Wikipedia is a good source of further basic information.

## Addresses

In order to use the tester, you need to know the device addresses. Every type of IC has a base address. Some examples are:

8574 port expander: 0x40 = 64 (decimal)

PCF8591 A/D converter: 0x90 = 144 (decimal)

EEPROMs: 0xA0 = 160 (decimal)

PCF8583 clock IC: 0xA0 = 160 (decimal)

The address byte contains eight bits. With the usual 7-bit addressing scheme, the remaining bit is used to control the data transfer direction. The master uses this bit to indicate whether it wishes to send or receive data, and it is called the ‘R/W bit’. For example, ‘A1’ (decimal 161) can be used to address an EEPROM for reading. When an address is placed on the bus, the addressed device acknowledges receipt of the address, which also indicates that it is ready to receive or send data. If the master does not receive an acknowledgement form the addressed slave, the address was not received correctly or the slave cannot receive or send data.

Many types of ICs allow the last three bits to be used as subaddresses. They thus have three pins that can be connected to GND (‘0’) or $V_{CC}$ (‘1’) as appropriate. For example, you can connect eight PCF8574 ICs to the same bus and address them individually.

A full bus cycle is shown in schematic form in **Figure 5**. It begins with a start

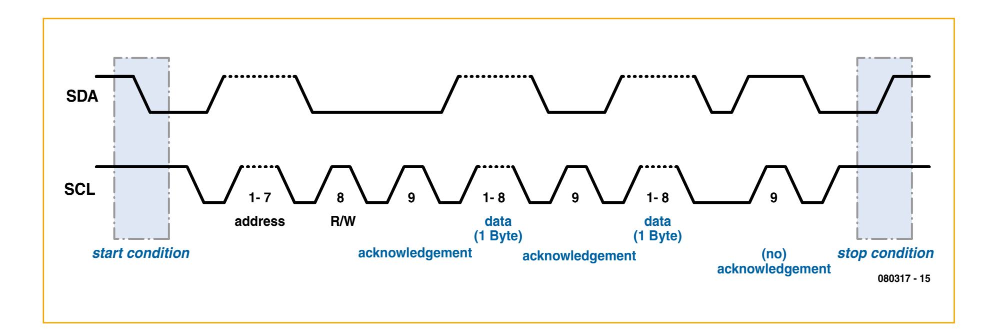



Figure 5. Data transfer with addressing and acknowledgement.

condition, which is followed by the address and R/W bit. After this, you can see the acknowledgement, which is followed by a byte transmitted by the master. After this byte is acknowledged, the master sends the next byte. It is also acknowledged by the slave. As the master does not have any more data to send, it generates the stop condition.

## Minimal hardware

In order to use the I²C bus, you have to put together a pull-up adapter (**Figure 6**). A 2.2-kΩ resistor must be connected to each of the two bus lines (serial clock (SCL) on PC5 and serial data (SDA) on PC4) to pull them up to +5 V (**Figure 7**).
If you want to connect more than one device to the bus, the bus port must have more than one socket or one set of pins. **Figure 8** shows a serial EEPROM with a capacity of 4 Kbits (such as an ST24C04MN) connected to the bus. Here the test adapter is connected directly to the IC socket. In other situations, you could connect the tester to one or more ICs on a prototyping stripboard or a printed circuit board.

## Tester software

A program that you can use for initial testing is available for download from the Elektor website or the Computer: club² website. It supports several simple commands that can be used for communication with the I²C bus interface via the serial port of a PC. Load the program *ATM18_I2C_Tester* in the microcontroller and connect the system under test to a terminal emulator program using communication port settings 38400, N, 8, 1.

The following start message will appear after a reset:
*ATM18 I2C_Tester V1.2*

If you press the question mark key (?) in response, a list of the available commands will be displayed. There are two types of commands: low-level commands and high-level commands, which are specifically designed for controlling EEPROMs. The command interpreter acknowledges each issued command with a number in the range of 0–3:
0 = Command executed
1 = Unknown command
2 = Incorrect or missing parameter(s)
3 = Error during command execution

The most important **low-level commands** are:

STA = Set start condition
STP = Set stop condition
DRB = Direct read byte
DWB = Direct write byte

In theory, you can control any I²C IC with these commands. For example, suppose you want to send a byte to a PCF8574 port expander to define the states of its eight outputs.

Here you must remember that all data is output in hexadecimal form, so the address is ‘40’ (short for ‘0x40’) rather than ‘64’. The data byte is ‘55’ (decimal 85 or binary 01010101), which means that after the transfer is completed alternating port pins are high and low, which you can easily check with a meter or logic tester.

| **Command:** | **Response:** |
|---|---|
| STA // Start condition | 0 // Executed |
| DWB 40 // Slave address | 0 // Executed |
| DWB 55 // Data byte | 0 // Executed |
| STP // Stop condition | 0 // Executed |

Now you can also read data from the IC. Naturally, you expect the output states you read back be the same as what you sent. Here the address is ‘0x41’ because the R/W bit must be set to 1. And indeed, you see that the read byte is ‘0x55’.

| **Command:** | **Response:** |
|---|---|
| STA // Start condition | 0 // Executed |
| DWB 41 // Slave address | 0 // Executed |
| DRB 0 // Read without ack | 55 // Port data |
| STP // Stop condition | 0 // Executed |

For another example of using low-level commands, you can write a byte to a 24C04 EEPROM with address ‘0x00’ as follows:

Figure 6. Test adapter construction.

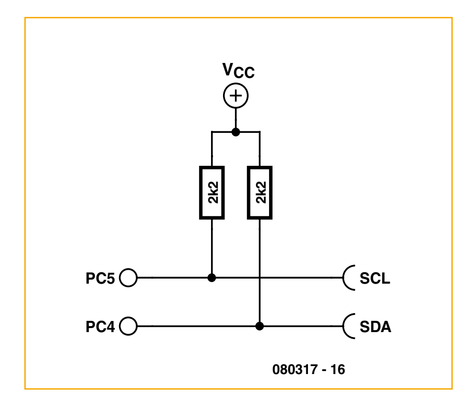



Figure 7. Schematic diagram of the adapter.

| Command: | Response: |
|---|---|
| STA // Start condition | 0 // Executed |
| DWB A0 // Slave address | 0 // Executed |
| DWB 00 // Byte address | 0 // Executed |
| DWB 11 // Data byte | 0 // Executed |
| STP // Stop condition | 0 // Executed |

To read data from the EEPROM, you must first send the internal address of the desired data with the R/W bit set to 'write'. After this, you must send the address again with the R/W bit set to 'read' in order to read one or more bytes. The following example with low-level commands demonstrates reading one byte from address '0x00':

| Command: | Response: |
|---|---|
| STA // Start condition | 0 // Executed |
| DWB A0 // Slave address | 0 // Executed |
| DWB 00 // Byte address | 0 // Executed |
| STA // Restart | 0 // Executed |
| DWB A1 // Slave address | 0 // Executed |
| DRB 0 // Read without ack | 11 // EEPROM data |
| STP // Stop condition | 0 // Executed |

**High-level commands**
With the high-level commands, you only have to specify the slave address and the byte address in order to read or write an EEPROM directly. The interpreter handles the addressing and generates the start and stop conditions all on its own. Here again, all data is communicated in hexadecimal form.

RSB = Read single byte
RDB = Read double byte
RMB = Read multiple bytes

WSB = Write single byte
WDB = Write double byte
WMB = Write multiple bytes

'Set' commands:
SA = Set slave Address
BA = Set byte address

'Get' commands:
SA? = Get slave address
BA? = Get byte address
IDN? = Get identity string
? = Get help

**High-level examples**
Writing several bytes to a 24C04 EEPROM starting at address '0x00':

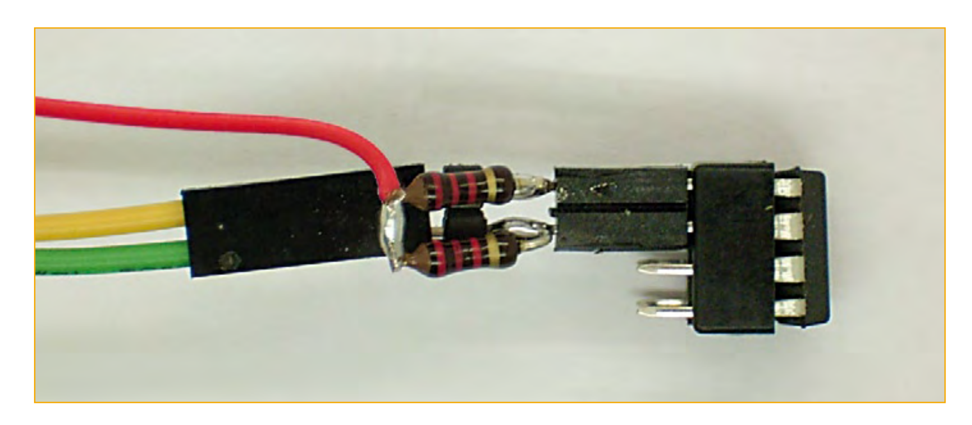


Figure 8. Testing a 14V04 EEPROM.

| Command: | Response: |
|---|---|
| SA A0 // Slave address | 0 // Executed |
| BA 00 // Byte address | 0 // Executed |
| WMB 11 22 33 44 55 // 5 bytes | 0 // Executed |

Reading several bytes from a 24C04 EEPROM starting at address '0x00':

| Command: | Response: |
|---|---|
| SA A0 // Slave address | 0 // Command execution acknowledgement |
| BA 00 // Byte address | 0 // Command execution acknowledgement |
| RMB 5 // Read 5 bytes | 11,22,33,44,55// EEPROM data |

## Reserved addresses and 10-bit addressing

Certain I²C addresses are reserved and cannot be used for connected devices. Due to these reserved addresses, only 112 of the 128 addresses possible with 7-bit addressing are available for use.

| Address | R/W bit | Description |
|---|---|---|
| 0000000 | 0 | General call address |
| 0000001 | x | CBUS address |
| 0000010 | x | Reserved for a different bus format |
| 0000011 | x | Reserved for future expansion |
| 00001xx | x | Reserved for future expansion |
| 11111xx | x | Reserved for future expansion |
| 11110xx | x | R8C/13 applications |

In order to handle a growing number of new I²C ICs, 10-bit addresses were introduced. This makes it possible to address up to 1024 devices on a single bus. Thanks to the use of previously unused addresses in the '1111 '0xx' range together with the R/W bit, there is no interference to 7-bit devices on the same bus, so 7-bit and 10-bit devices can be used together on the same bus.

| 10-bit marker | | Address part 1 | R/W bit | | Address part 2 | |
|---|---|---|---|---|---|---|
| 11110 | XX | | X | Acknowledge 1 | XXXXXXXX | Acknowledge 2 |

The five bits of the reserved address '11110' are sent first, followed by the first two bits of the device address. The R/W bit is sent next, since an acknowledgement follows every byte. Of course, more than one device may respond to the first part of the address, and they can all send an acknowledgement. The second part of the address is sent after the acknowledgement. All bus devices selected by the first part of the address also decode the second address byte. In a properly configured network, there can be only one device that generates an acknowledgement after this. Now the communication can begin.

## Listing 1
### Finding addresses with Bascom

```
'ATM18 I2C tester
'I2C: SCL = PC5, SDA = PC4

$regfile = "m88def.dat"
$crystal = 16000000
Baud = 38400

Dim N As Byte

  Config Portb = Output
  Config Scl = Portc.5
  Config Sda = Portc.4

  Print "ATM18 I2C ad-
   dress test"

  For N = 2 To 254 Step 2
    I2cstart
    I2cwbyte N
    If Err = 0 Then Print N
    I2cwbyte 0x55
    I2cstop
  Next N
End
```

## Listing 2 Writing data to an EEPROM

```
$regfile = "m88def.dat"
$crystal = 16000000
Baud = 38400
Dim N As Byte
Dim Adr As Word
Dim H As Byte
Dim L As Byte
Dim Dat As Byte
  Config Portb = Output
  Config Scl = Portc.5
  Config Sda = Portc.4
  Print "ATM18 24C512 write"
  For Adr = 0 To 1000
   Input Dat                'start
   I2cstart
   I2cwbyte 160             'slave adsress 24C512
   H = High(adr)
   L = Low(adr)
   I2cwbyte H               'high address
   I2cwbyte L               'low address
   I2cwbyte Dat             'write byte
   I2cstop                  'stop
  Next Adr
End
```

## Finding addresses with Bascom

In a situation where several ICs with jumper-programmable subaddresses are present on a bus or you want to investigate an unknown system, you often do not know the I²C slave addresses. A small program written with Bascom can help here. It tries each address in turn to see whether a device responds. Each time an address is sent, the system variable ERR is assigned a '1' if no acknowledgement is received or to '0' if an acknowledgement is received, which means that the address is valid. The program tests all even-numbered addresses in the range of 0 to 254, since the corresponding odd-numbered addresses would be the read address of the same ICs.

This program (see **Listing 1**) generates a list of addresses in decimal notation, such as the following example:

ATM18 I2C address test
64
144
160
162

Here the ICs show in **Figure 1** were found. Although the PCF8583 clock IC has the same base address as every EEPROM, in order to avoid an address conflict its subaddress is altered by connecting its A0 pin to $V_{CC}$ so that it appears at address '162' instead of address '160'.

## Writing data to an EEPROM

Here we use a 24C512 EEPROM, which has a total capacity of 64 KB. This relatively large address space requires using a 16-bit address for the stored data. Consequently, two internal address bytes are sent after the I²C addressing cycle. They are followed by one or more data bytes. The program (see **Listing 2**) receives individual bytes from the serial interface and stores them in the EEPROM starting at address '0'.

## Data output to a port expander

The objective here is to read data from an EEPROM and transfer it to a PDF9574 port expander. This gives you a basic tool for software control of all types of devices and machinery. The program (see **Listing 3**) also transmits the data via the serial interface for auditing or checking.
Reading the individual bytes from the EEPROM requires the same actions as for low-level control of the 24C04, except that here the byte address is transmitted in two parts (high byte and low byte). After this, the I²C address must be sent again with the R/W bit set to 'read'(address '161' instead of '160') in order to read the data. ACK is used in I2CRBYTE for the actual reading process, and if more than one byte must be transferred, the final byte is fetched with NACK.

(080317-I)

## The ATM18 project at Computer:club²

ATM18 is a joint project of Elektor and Computer:club2 (*www.cczwei.de*) in collaboration with Udo Jürß, the editor in chief of *www.microdrones.de*. The latest developments and applications of the ATM18 are presented by Computer:club² member Wolfgang Rudolph in the CC2-tv programme broadcast on the German NRW-TV channel. The ATM18-AVR board with the I²C tester was featured in ***instalment 24*** of CC²-tv, which was first broadcast on 23 October 2008.

CC2-tv is broadcast live by NRW-TV via the cable television network in North Rhine–Westphalia and as a LiveStream programme via the Internet (www.nrw.tv/home/cc2). CC2-tv is also available as a podcast from www.cczwei.de and – a few days later – from sevenload.de.

# RS Embedded Develo

Jan Buiting (Elektor UK Editorial)

**RS Components has launched a unique concept that's claimed to revolutionise the way you design. Like most good ideas, it's deceptively simple – a universal and reusable Baseboard to provide a single platform to evaluate different microcontrollers and applications.**

Staying abreast of technology is an expensive business, especially in electronics design. Each time you need to upgrade to a new processor, your old development kit goes in the bin. This leaves you not only with the expense of buying a new one, but with the hassle of interfacing both software and hardware to existing application circuits. RS Components now offers a permanent solution to this perennial problem – the RS Embedded Development Platform, or RS EDP.

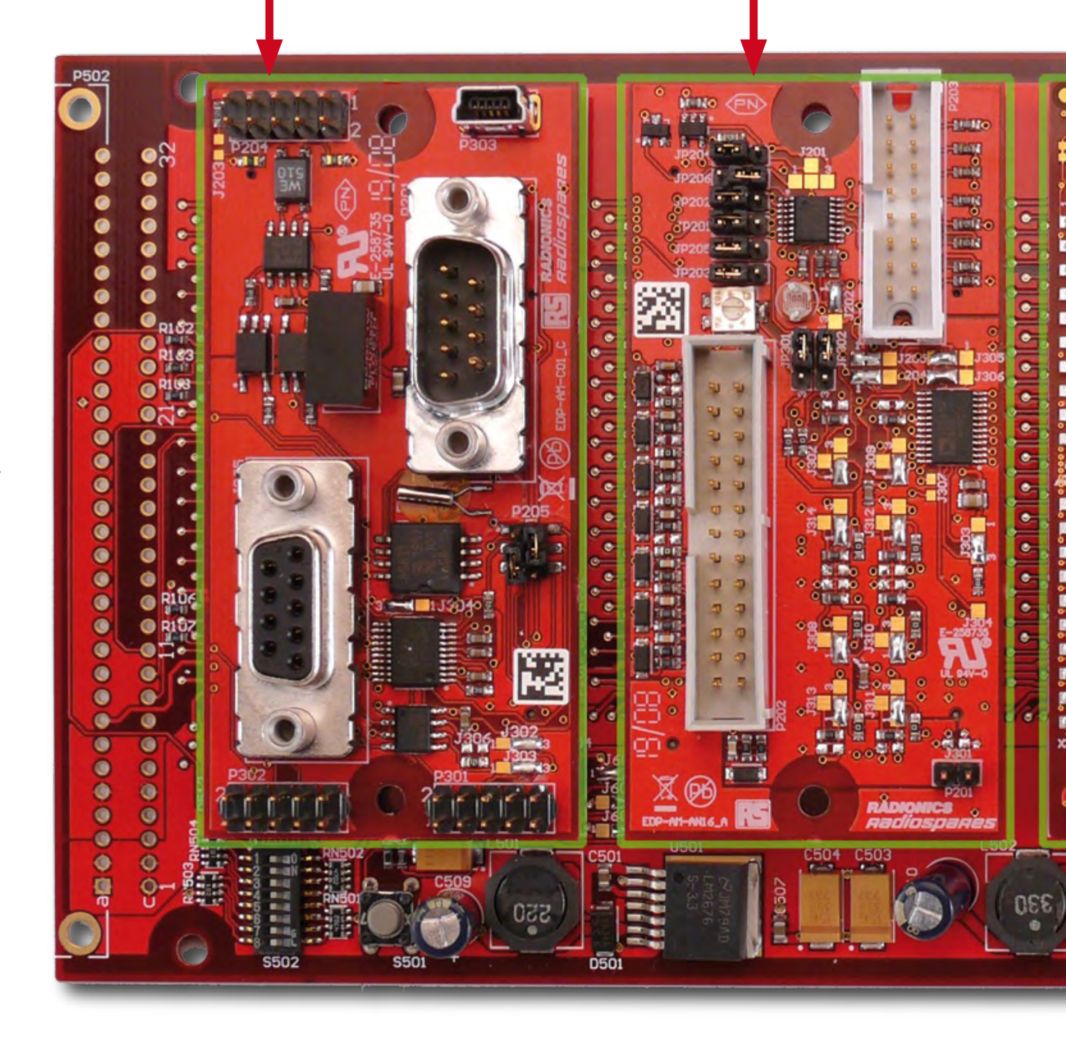
Their single, reusable platform means you can drastically reduce product design cycles and gain a competitive advantage in bringing products to market — fast! What's more, RS have made software drivers, frameworks, full schematics, Gerber files and parts lists available online, IP free. So you can easily stay ahead of the game — the industrial variety, that is.

**Basic Communications Module**

USB • RS232 • RS485 • 2× CAN • RTC • 240 bytes NVRAM

**Analogue Input Module**

Interfacing of up to 28 analogue channels with the onboard MAX1138 ADC for extra 12 channels of 10-bit ADC



## A world first

RS claim this is the world's first development tool to provide options for different microcontroller manufacturers, technologies and applications on one platform. It consists of a robust, reusable Baseboard with four identical 'stations'.

Many permutations of microcontroller specific CPU (Central Processing Unit) Modules and Application Modules are possible. I found even with the minimum (out of the box) configuration of Baseboard and CPU module I was able to set up, using the supplied example code, a basic web server application through the standard on-board Ethernet connection.

## Faster, cheaper

The kit received from RS for this review succeeds in providing a hardware platform and software frameworks to allow

# pment Platform (EDP)

**Digital Input/Output Module**

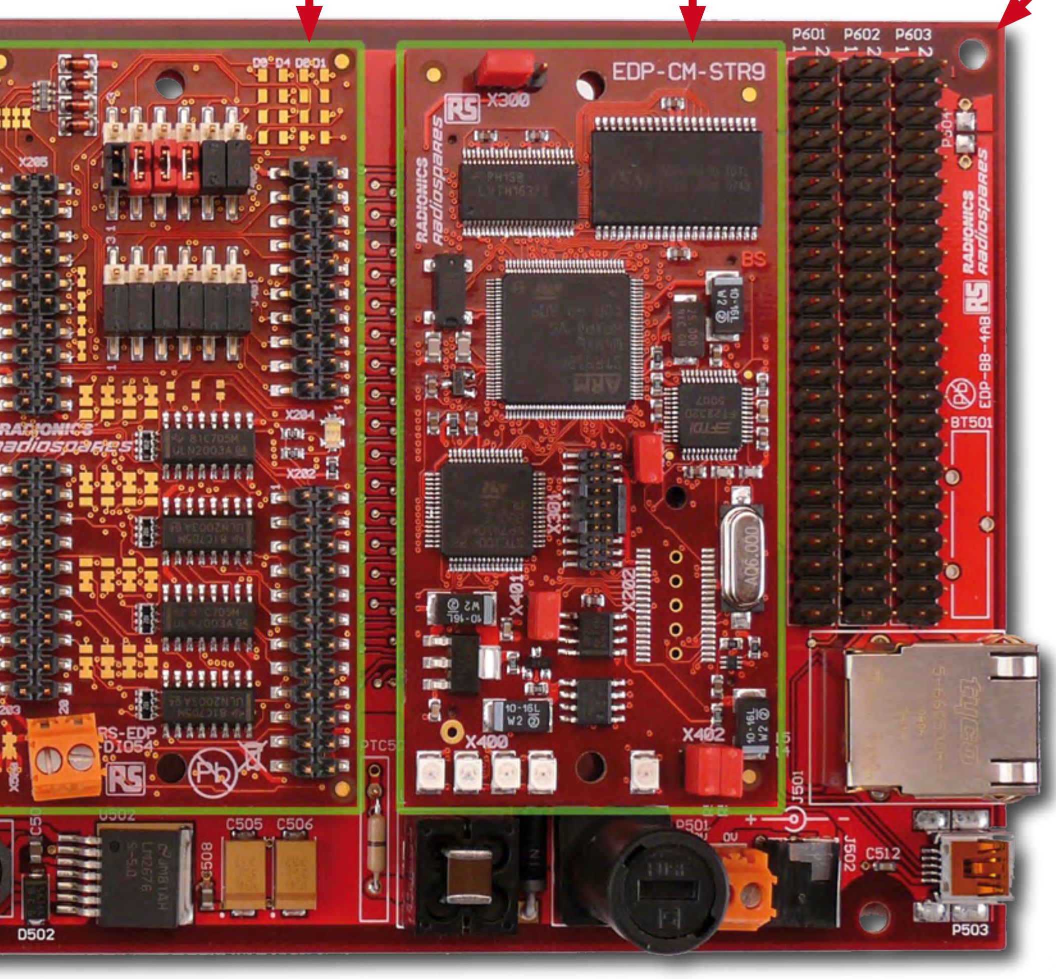
Interfacing of up to 12 channels • with overvoltage protection • 16 TTL inputs via I2C • 16 500 mA outputs • 16 25 mA logic outputs

**STR912 32-bit ARM9E™ CPU module**

96 MIPS • Ethernet • USB • I2C • CAN

**EDP baseboard**

3V3 and 5V regulators • 3× I2C • 2× CAN • extended Eurocard (200 × 100 mm) • 64-way DIN connector area for standard rack system backplane




you to quickly concentrate efforts on application and software development. I was unable though to substantiate RS' claim of customer trials having indicated "a reduction in the time and layout stage from the 13.2 week industry average to 8.5 weeks" — I am just an editor with less than 3 weeks to produce all of this month's Elektor articles (and a lot more).

## Assorted CPUs and modules

To accompany the launch of the EDP, RS developed a range of CPU and Application modules. The CPU modules released so far are the STR912 unit based on the ARM9 from ST Microelectronics, and an Infineon XC167 module that looks particularly suited for demanding industrial, motor control and automotive applications.

The CPU modules are complemented by a series of ready to use Application Modules ranging from motor control to communications. All are sturdily built, have a uniform footprint of 80 × 40 mm, two connectors and, it must be said, succeed in reducing circuit construction times significantly.

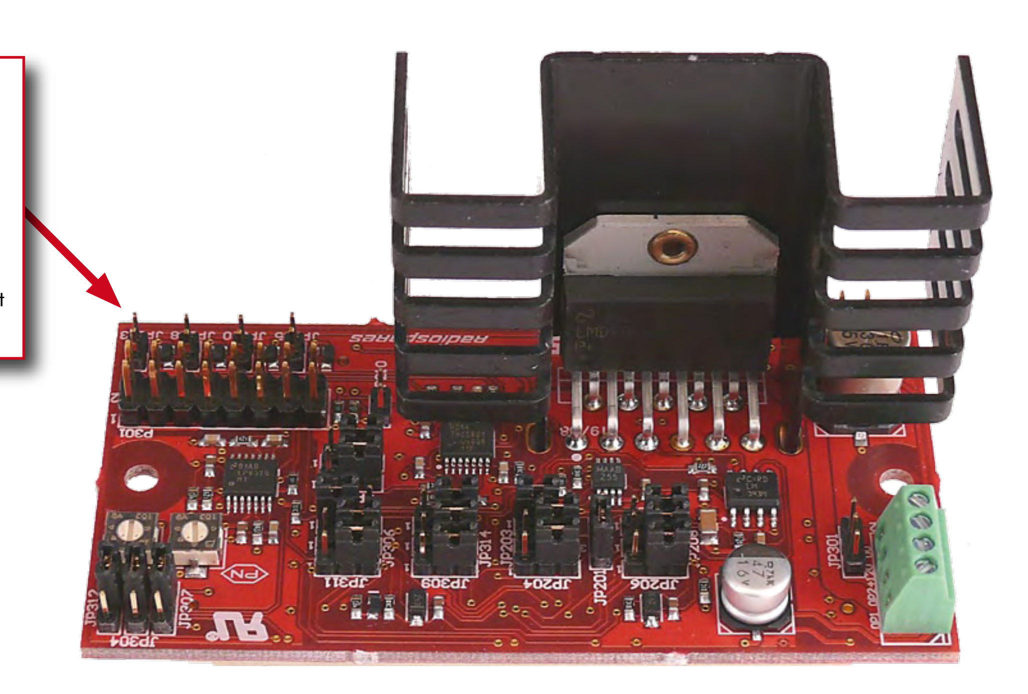
I hear that forthcoming modules, in the coming months, include the latest NXP ARM Cortex module which will allow developers to run NI LabVIEW natively as well as a module which will be able to host any of Microchip's Explorer 16 modules including the PIC24 Microcontroller, the dsPIC33 digital signal controller (DSC) families and the new 32-bit PIC32MX devices. What we really can't wait for though, are the application modules on the way, a powerful BLDC motor controller which will drive dual 24V, 4 A motors or triple 24 V 4 A brushed motors and Bluetooth, WiFi, FireWire and mass storage modules which will really make the EDP a versatile choice for new designs. Fingers crossed we'll see these followed by Atmel, Renesas or Freescale micros to mention but a few.

## Out of the box

The box I got from RS for the purpose of this article contained the following modules: ARM9 CPU; Digital; Ana-

**Brushed Motor Control Module (not plugged on)**

For brushed DC motors up to 12 V, 3 A • With external screw terminals to allow up to 5 A • LM18200 driver has inputs for: current sense, tacho gen., DC volts, 2 limit switches, chopper and quad encoder



logue; Comms; Motor Control and of course the Baseboard. This does not appear to be a standard complement sold by RS — the closest it comes to as compared to what customers can buy is the STR9 Foundation Kit (= Baseboard + STR9 CPU module + Comms module).

For a basic webserver all you need to have is the Baseboard, the ARM9 CPU module and of course Ethernet connectivity to the web and USB connectivity to the PC, not forgetting a wall wart 12-V DC adapter.
The use of two keyed connectors on each module (and on the base board) makes for ruggedness and reliability while precluding boards to be fitted the wrong way around. On the down side, the contact pressure is such that modules are hard to remove again (but is made a littler easier with the extraction tool provided). Also, with the CPU module installed there are only three free positions for apps modules left, which is a bit scanty. Fortunately, bus extension connectors are available at the edge of the EDP Baseboard and the 64-way DIN connector on the end allows the I2C and CAN control buses to be linked to other baseboards to provide more positions.

## Software complement

The real power of the EDP may well lurk in the industry-leading software suites that come with it, rather than the hardware. The CD with the kit is a breeze to use, although it will take 15 minutes or so to do a full installation using the recommended order. For the STR9 you install HiTOP for ARM, the Keil ARM Compiler, GNU for ARM and, optionally, FTDI drivers, plus a bunch of examples. In good USB fashion, you first do the software installation and only then connect the hardware! The Xc167 CPU module gets the following installed: Infineon DAS, HiTOP for 167, Keil C166, DAvE and again examples galore. More third-party support for the RS EDP (tested and untested!) is found in the Release Notes with the kit: IAR EWARM CSPY, Keil RV-MDK ARM and Rowley CrossWorks ARM 1.7.




## Pricing and availability

It must be said that the prices of the modules and starter kits restrict the EDP system to the realms of professional designers and software developers.

The STR9 Foundation Kit, for example, is priced at £ 359, while the individual application modules are around the £ 100 mark. But then such factors as money saved in terms of development time, the ability to switch CPU platforms rapidly, the flexibility of the system, the big names involved (including RS Components themselves), the lush software complement and other "company-internal considerations" may help application developers to convince many a Head of Engineering to sign an order for an EDP.

(080646-I)

## Internet Link

www.rswww.com/edp

# Hi-fi Wireless Head

## 2.4 GHz digital audio link

Christian Tavernier (France)

**Although they've been on the shelves of audio and video equipment retailers for quite a few years now, wireless headsets have been conspicuously absent from hobby electronics magazines. It has to be said that building this sort of headset, especially if we set ourselves a certain level of quality, is far from simple — or rather, *was* far from simple, until these recently-brought-out modules came along to help us out.**




Thanks to three new modules marketed by the Aurel company, it's now possible not just to build a wireless headset, but also to give it a level of performance that would make most commercial products green with envy. Before we go into greater detail at the end of the article, we can tell you right away that our headset offers distortion as low as 0.016% at 1 kHz and a signal-to-noise ratio of 75 dB; these are figures actually measured on the Elektor prototype between the transmitter input and the receiver headphone output socket, i.e. including the radio link; the connoisseurs will appreciate this!

### Overview

Our wireless headset obviously consists of two separate elements: a transmitter designed to be connected to any audio or video source (CD or DVD player, TV, stereo, etc.) and a receiver to which you can connect any headphones you like. It's worth choosing very high quality ones, given the performance of the transmitter/receiver combination. The project can also be used just as a wireless audio link without a headset. Several systems can be used at the same time, so you could, for example, build a wireless 5.1 surround system.

In the field of wireless headsets, there are currently two competing technologies: infrared and radio link. As far as we are concerned, and given the spec of these Aurel modules, we opted for the radio link, operating here in the 2.4 GHz band, on frequencies that are of course legally authorized in most countries.

Construction is extremely simple, easily within the capacities of any amateur who know how to hold a soldering iron (by the right end!)

### The Aurel 2.4 GHz audio modules

Intended to gradually supersede Aurel's earlier TX FM audio and RX FM audio modules, these three new modules enable a leap forward in terms of quality. These are genuine digital audio modules, i.e. the LF signals are converted to digital at the transmitter. They are then transmitted in digital form, making them immune to the distortion and noise that affect analogue radio transmissions, to be converted back to analogue in the receiver.

On the transmitter side, there are two different modules, the TX-AUDIO-2.4 and the more recent TX-AUDIO-2.4/AE. In terms of performance, the two modules are virtually equivalent, and our project can use either equally well. The

# set




## Technical specifications

(transmitter/receiver distance: 0.5 m)

| | |
|---|---|
| Frequency response: | 18.5 kHz |
| Distortion THD + N:. | 0.009 % (100 Hz, B = 22 kHz) |
| | 0.016 % (1 Hz, B = 22 kHz) |
| | 0.06 % (10 kHz, B = 22 kHz) |
| | 0.36 % (10 kHz, B = 80 kHz) |
| SNR: | 75 dB (B = 22 kHz) |
| | 82 dBA |
| L/R separation: | 78 dB (1 kHz) |
| | 57 dB (20 kHz) |

**Receiver**

Min. supply: +7.5 V / –3.5 V (negative voltage for 2 Vrms output)

Current consumption: +97 mA / –16 mA

Max. output voltage: 5.7 V

Output impedance: 100 Ω

Balance control attenuation (at centre): 3.5 dB

**Transmitter**

Min. supply voltage: 6 V

Current consumption: 72 mA

Max. input voltage: 1.92 V

Input impedance: 32 kΩ (20 kΩ at module input)

Frequencies:

2.3979 GHz (OB closed, CH open, power on)
2.4096 GHz (SW0/1/2 = open/open/open, CH closed)
2.4186 GHz (SW0/1/2 = closed/open/open, CH closed)
2.4276 GHz (SW0/1/2 = open/closed/open, CH closed)
2.4368 GHz (SW0/1/2 = on/on/open, CH closed
2.4458 GHz (SW0/1/2 = open/open/closed, CH closed)
2.4548 GHz (SW0/1/2 = closed/open/open, CH closed)
2.4639 GHz (SW0/1/2 = open/closed/closed, CH closed)
2.4728 GHz (SW0/1/2 = closed/closed/closed, CH closed)
2.4458 GHz (CH open)

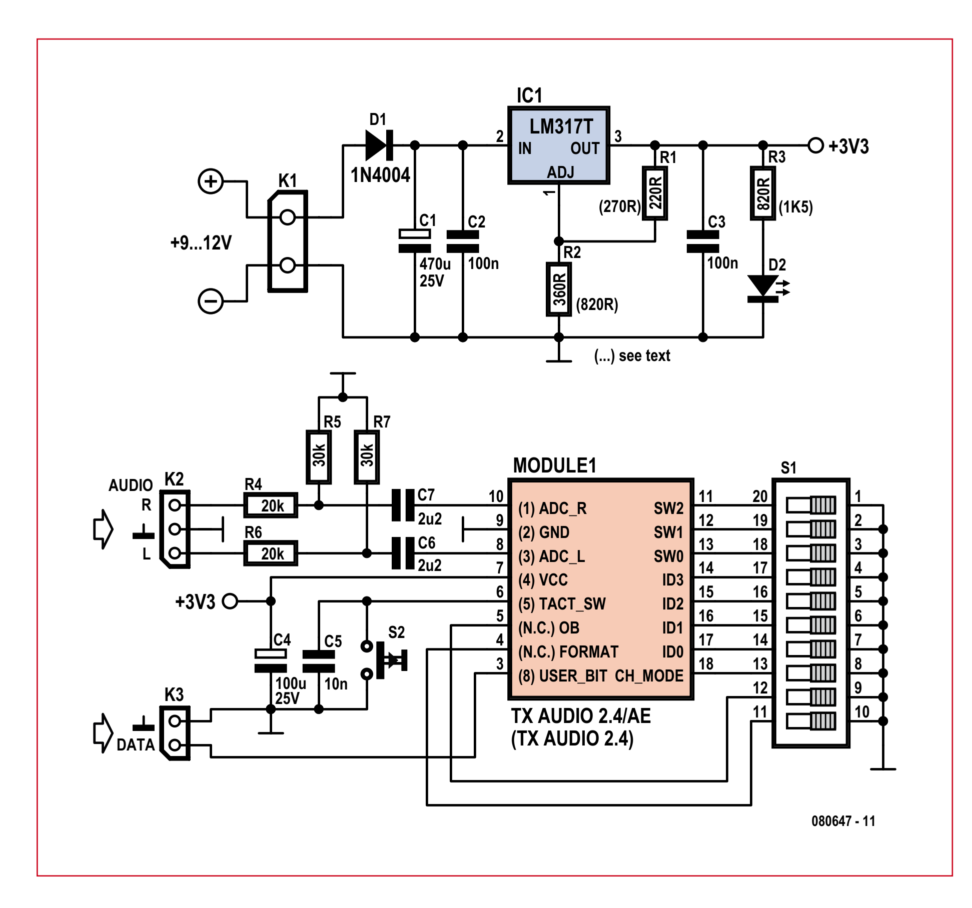



Figure 1. Transmitter circuit. If you use the 2.4 module, make sure you use the values in brackets for R1, R2, and R3.

only 'visible' differences are the channel select system, which is a little more comprehensive on the -AE model, and the pin-outs, which are not quite identical. In addition, both modules also let you transmit digital data at 5 kbit/s along with the audio signal.

The principal specifications of all these module are given in **Tables 1 and 2**.

## Transmitter circuit

Given the high level of integration of the Aurel transmitter modules, the circuit for our project is extremely simple, as you can see in **Figure 1**.

Powering is entrusted to a 'plug-top' mains unit that needs to provide a DC voltage between 7.5 V and 10 V at 120 mA minimum. This voltage doesn't need to be stabilized, as it is stabilized in the transmitter by IC1, an LM317 whose output voltage is defined by the ratio of resistors R1 and R2. This slightly complicated power supply arrangement was necessary because Aurel has had the 'bright' idea of powering the 2.4 module at 5 V and the 2.4/AE at 3.3 V. Use the values of R1, R2, and R3 in brackets for the 2.4 module.

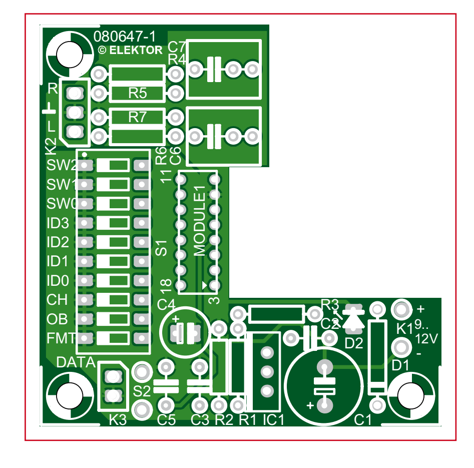
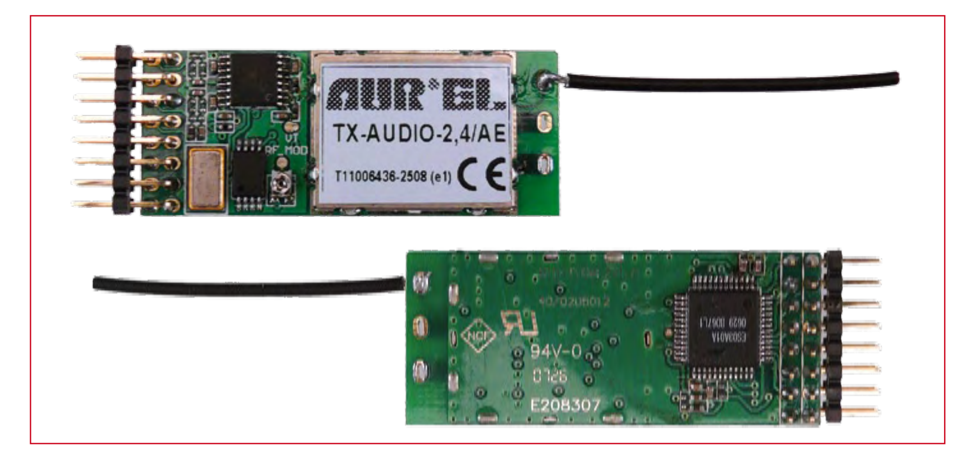



Figure 2. Transmitter circuit board.




Transmitter

## COMPONENTS LIST transmitter

**Resistors**
**0.5 or 0.25 watt, metal film, 5%**
R1 = 220Ω (270Ω for 2.4 module)
R2 = 360Ω (E96: 357Ω) (820Ω for 2.4 module)
R3 = 820Ω (1kΩ5 for 2.4. module)
R4,R6 = 20kΩ0
R5,R7 = 30kΩ0 (E96: 30kΩ1)

**Capacitors**
C1 = 470µF 25V radial, lead pitch 5mm
C2,C3 = 100 nF ceramic, lead pitch 5mm
C4 = 100µF 25V radial, lead pitch 2.5 mm
C5 = 10 nF ceramic, lead pitch 5mm
C6,C7 = 2µF2 MKT, lead pitch 5 or 7.5mm

**Semiconductors**
D1 = 1N4004
D2 = LED, red, low current
IC1 = LM317 (TO220)

**Miscellaneous**
K1 = PCB screw terminal block, lead pitch 5mm
K2 = 3-way pinheader
K3 = 2-way pinheader
S1 = DIL switch block, 10 contacts
S2 = pushbutton, 1 contact
Module1 = TX-AUDIO-2.4/AE (Aurel.) + 2 x 8 pin connector with 2.0 mm lead pitch (e.g. Molex type 872641652, Farnell # 856-0145)
PCB, no. **080647-1**

**Table 1. Principal specifications of the Aurel TX Audio 2.4 and TX Audio 2.4/AE modules** (Aurel figures).

| Parameter | TX-Audio-2.4 | | | TX-Audio-2.4/AE | | | Units |
|---|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Supply voltage | 3,6 | – | 5 | 2 | – | 3,4 | V |
| Power consumption | – | 93 | – | – | 68 | – | mA |
| Frequency range | 2,400 | – | 2,4835 | 2,400 | – | 2,4835 | GHz |
| Frequency stability | – | +/-100 | – | – | +/-100 | – | kHz |
| RF power | – | 10 | – | – | 10 | – | dBm |
| Number of channels | – | 8 | – | – | 8 | – | – |
| Frequency response (–1 dB) | 20 | – | 20 000 | 20 | – | 20 000 | Hz |
| Dynamic range | – | 92 | – | – | 90 | – | dBm |
| Channel separation | – | 80 | – | – | 70 | – | dB |
| Signal-to-noise ratio | – | 87 | – | – | 90 | – | dB |
| Input impedance | >10 | – | – | >10 | – | – | kΩ |
| Operating temperature | –10 | – | +80 | –10 | – | +60 | °C |

The audio source connected to K2 is isolated from the transmitter by capacitors C6 and C7; despite their high values, these must not under any circumstances be electrolytics, in order to maintain the overall quality of the link.

Push-button S2 enables you to change the transmit channel. If you use the 2.4/AE module, the right-hand part of **Figure 1** comes into play, and lets you set the transmit channel 'manually' using the top three switches of S1, S2 then being inactive. The other switches on S1 allow us to experiment with the other options available in the 2.4/AE module, as shown in **Table 3**.

One other interesting option of the modules, accessible via K3, is the additional channel for transmitting digital data at a maximum rate of 5 kbits/s.

## Constructing the transmitter

As seen in **Figure 2**, the suggested PCB is L-shaped, as the transmitter modules have components on both faces, which means they can't be mounted onto the PCB, even though the small size of their connector really demands it.

Watch out for the 16-pin female connector for this module: it's a 2 mm pitch type, available from Farnell, for example. Take care as well to select the correct values for R1, R2, and R3, depending on which of the Aurel modules you've chosen, as shown in the circuit, as the 2.4/AE module really doesn't like being powered from 5 V!




Before plugging the module into the female connector on the PCB, note that if it's a 2.4 with a single-row connector, it plugs into the bottom row of the female connector, with the side marked "Aurel Tx-Audio-2.4" up, as in the photos of our prototype. If it's a 2.4/AE, it takes up all of the female connector. The transmitter can't be tested without its associated receiver, so let's take a look at that right away.

## Receiver circuit

The receiver circuit shown in **Figure 3** is a little more complicated than the transmitter, mainly because of the headphone amplifier, which we wanted to be as good quality as the Aurel modules it goes with.
The receiver has the same DIL switches S1 and push-button S2 as the transmitter, with the same functions, but you don't have to fit them if you don't want to, as when it is no longer receiving any signal, the receiver module automatically starts scanning the 8 channels it can receive and locks onto the first one it detects. So if you're only using one transmitter with it, which is usually the case, the link is set up all by itself, and to confirm this, pin 2 of the module goes to 2.7 V, as shown by D3 lighting, after amplification in T1. See **Table 4** for the other channel select modes — four in all — that can be configured using S1-8 and a jumper on J1.

The audio outputs are available on pins 8 and 10 and drive two identical channels. A first stage, built around IC2A (or IC2B), forms a second-order Sallen & Key low-pass filter. This lets us cut off everything above 24 kHz, thereby

Figure 3. Receiver circuit.

eliminating the residual digital artefacts from the Aurel modules. Without the filter, overall distortion is around 0.5–1%, but drops to 0.016% with it. This filter is followed by the dual-gang balance pot P2 in conjunction with the volume pot P3.

The 'power' — if we can call it that, for a headset — amplifier is formed by the dual op amp IC3 chosen, like IC2, from the range of excellent audio models from the now-defunct Burr Brown (now part of Texas Instruments) with type number OPA 2134. This IC offers extremely low inherent distortion and noise, and is perfect for this project.

The amplifiers are powered from a split power rail with respect to ground, with the aim of eliminating the 'big' electrolytic output capacitors that would oth-

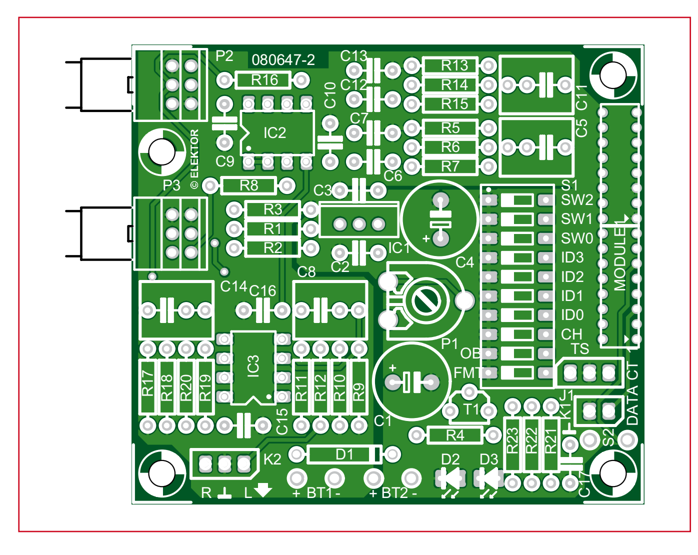
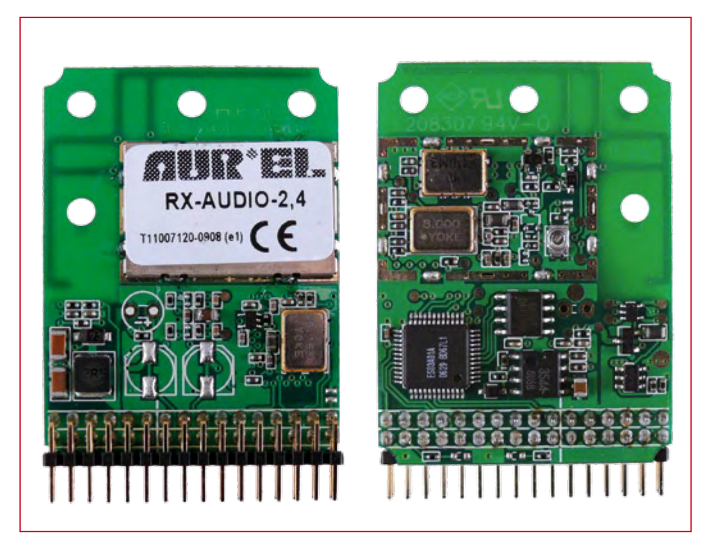


Figure 4. Receiver circuit board.



The Aurel digital audio modules

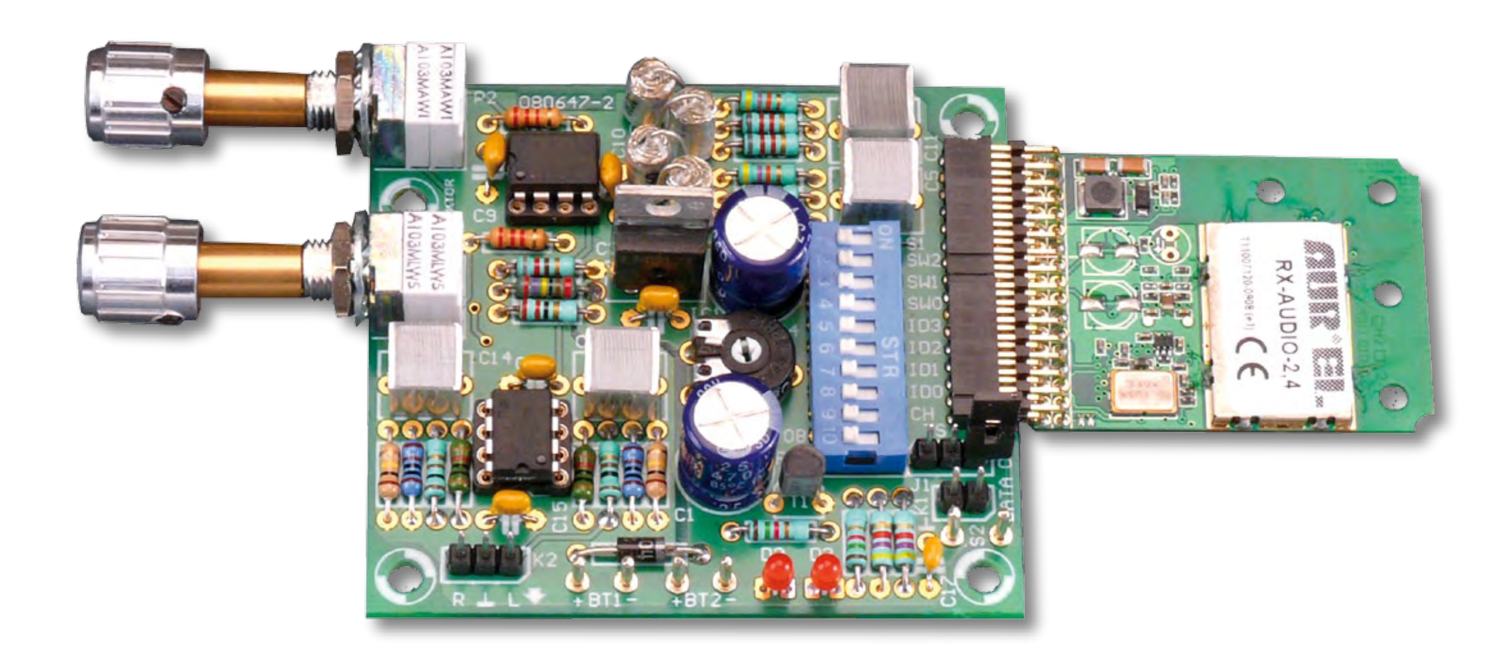
## COMPONENTS LIST
## receiver

**Resistors**
**0.5 or 0.25 watt, metal film, 5%**
R1 = 270Ω
R2 = 22Ω
R3 = 820Ω
R4,R23 = 1kΩ5
R5,R13 = 47kΩ
R6,R7,R14,R15 = 8kΩ2
R8,R16 = 2kΩ2
R9,R17 = 100kΩ
R10,R18 = 1kΩ
R11,R19 = 10kΩ
R12,R20 = 100Ω
R21,R22 = 4kΩ7
P1 = 50Ω preset
P2 = 10kΩ potentiometer, dual linear (Vishay-Sfernice type P9A2RFISX1BB2103MAE3)
P3 = 10kΩ potentiometer, dual logarithmic (Vishay-Sfernice type P9A2RFISX1BB2103MLE3)

**Capacitors**
C1,C4 = 470µF 25V, radial, lead pitch 5mm
C2,C3,C9,C10,C15,C16 = 100nF, ceramic, lead pitch 5mm
C5,C8,C11,C14 = 2µF2, MKT, lead pitch 5 or 7.5mm
C6,C12 = 820pF
C7,C13 = 560pF
C17 = 10nF ceramic, lead pitch 5mm

**Semiconductors**
D1 = 1N4004
D2,D3 = LED red, low current
T1 = BC547B
IC1 = LM317 (TO220)
IC2,IC3 = OPA2134PA (DIP8)

**Miscellaneous**
K1 = 2-way pinheader
K2 = 3-way pinheader
J1 = 3-way pinheader with jumper
S1 = DIL switch block, 10 contacts
S2 = pushbutton, 1 contact
BT1,BT2 = 9V PP3 battery with clip-on lead (optionally with double-pole switch)
Module1 = RX-AUDIO-2.4 (Aurel) + 2 off 2 x 8 contacts with 2.0mm lead pitch (e.g. Molex type 872641652, Farnell # 856-0145)
PCB no. **080647-2**




erwise be needed. Despite the receiver's consumption of nearly 100 mA, we've used two 9 V batteries in the 6F22 (PP3) format. If you're sure you won't ever connect the batteries the wrong way round, you can replace D1 with a wire link and gain a little longer battery life. Another option would be to use 12 rechargeable AA cells in series, tapping off the ground at 4.8 V, i.e. after 4 cells, giving power rails of +9.6 V and –4.8 V. The circuit copes perfectly well with this asymmetry. According to its data sheet, the Aurel module must be powered from 5 V ± 0.1 V, corresponding to a precision of 2%. Pot P1 in conjunction with R2 makes it possible to adjust the voltage to 5 V exactly.

**Table 2. Principal specifications of the Aurel RX Audio 2.4 modules** (Aurel figures).

| Parameter | RX-Audio-2.4 | | | Units |
|---|---|---|---|---|
| | Min. | Typ. | Max. | |
| Supply voltage | - | 5 | - | V |
| Power consumption | - | 65 | - | mA |
| Frequency range | 2,400 | - | 2,4835 | GHz |
| Frequency stability | - | +/-100 | - | kHz |
| Sensitivity | - | -83 | - | dBm |
| Number of channels | - | 8 | - | - |
| Frequency response (–1 dB) | 20 | - | 20 000 | Hz |
| Dynamic range | - | 92 | - | dBm |
| Channel separation | - | 80 | - | dB |
| Signal-to-noise ratio | - | 87 | - | dB |
| Operating temperature | -10 | - | +60 | °C |

**Table 3. The function of the DIL switches on the transmitter and receiver.**

The receiver and 2.4/AE transmitter have all the options, unlike the 2.4 transmitter. The ID bits make it possible to use several wireless systems in parallel without interference. In this way, a wireless 5.1 system is easy to achieve.

| S1 | Module 1 | Function |
|---|---|---|
| S1-1 | SW2 | Channel select, bit 2 |
| S1-2 | SW1 | Channel select, bit 1 |
| S1-3 | SW0 | Channel select, bit 0 |
| S1-4 | ID3 | Identification bit 3 (2.4/AE) |
| S1-5 | ID2 | Identification bit 2 (2.4/AE) |
| S1-6 | ID1 | Identification bit 1 (2.4/AE) |
| S1-7 | ID0 | Identification bit 0 (2.4/AE) |
| S1-8 | CH_MODE | Use S2 to select channels |
| S1-9 | OB | Out-of-band communication for testing (2.4/AE) |
| S1-10 | FORMAT | Encrypted (2.4/AE) |

## Constructing the receiver

The suggested PCB is shown in **Figure 4** and doesn't present any particular problems in construction. However, sourcing the components is worth a few comments.
The OPA 2314s are available from Farnell or RS Components, for example. The same goes for the pots we've used, from the special audio range by Vishay-Sfernice in order not to degrade the performance of our system by using types that might have the ill grace to start 'crackling' after only a few uses.
Just as for the transmitter, the female connector for the receiver module is a 2 mm pitch type, but needs to have 2 rows of 16 contacts. As such a type doesn't seem to exist, we used two 2×8-contact types stacked end-to-end.

Although in tricky reception conditions LED D3 can be quite handy, to see if the receiver has indeed been able to find the signal, it is entirely optional, especially if you are keen to minimize power consumption.

## Tests and measurement results

Given the cost of the Aurel modules, it's wise to carry out a few simple checks before powering up the project.
On the transmitter side, check that regulator IC1 is indeed supplying the correct voltage required by the module you're using before you plug it into its connector. Re-read if necessary what we've said above about the correct position for it in the connector.
On the receiver side, check too that the supply to the Aurel module is indeed 5 V ± 0.1 V.
If all is well, plug the modules and ICs into their respective sockets and apply the power. LED D3 on the receiver should light very quickly if you are in automatic channel search mode. Otherwise, and if you are using a 2.4/AE transmitter module, it will only light if DIL switches S1-1 to 7 are set the same on both transmitter and receiver. You can then connect an audio source to the transmitter and note the fine quality of the whole link via the receiver headset,.
Even though the author — a serious hifi enthusiast — (still) has fairly reliable ears, a few measurements were added to support the good impression left by the first listening. In order for these to be meaningful, they were made over the whole of the audio chain, i.e. from the transmitter input to the receiver output.
The signal-to-noise ratio is better than on many commercial audio amplifiers used in headphone mode, while the distortion, even though it does increase slightly above 5 kHz because of the digital conversion technique used, is still way below what even the most experienced ears can hear.
The sound level that can be achieved from the headphone output using the OPA 2134 is more than adequate, whether you use a medium- or low-impedance headset, and will even let you damage your eardrums if you turn the volume up too high.
The frequency response, measured under the same conditions as the distortion, is from 15 Hz to 18.5 kHz at the –3 dB points. The power consumption is the sole drawback of this project, but unfortunately there's nothing we can do about that, as it's mainly due to the Aurel modules. It amounts to 72 mA for the transmitter and 97 mA/–16 mA for the receiver, with both LEDs lit.
Whether you've never used a wireless headset before, or have already been disappointed by certain commercial models, we have not the slightest hesitation in recommending this project which makes no compromises in terms of audio quality.

**Table 4. How to choose the receiver's various channel select modes (X = pin floating).**

| Mode | CH_MODE (S1-8) | TACT_SCAN (J1-1) | CT_INU (J1-3) | Function |
|---|---|---|---|---|
| DIP | GND | X | X | Channel selected by S1-1, S1-2, and S1-3 |
| TACT | X | GND | X | Channel change using S2 |
| TACT SCAN | X | X | GND | Performs a scan after S2 is pressed |
| AUTO SCAN | X | X | X | Automatic scan |

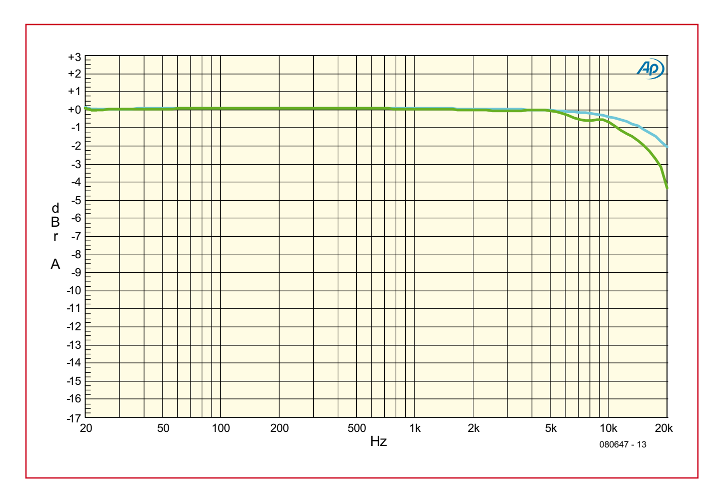



**Figure 5. Frequency response.**

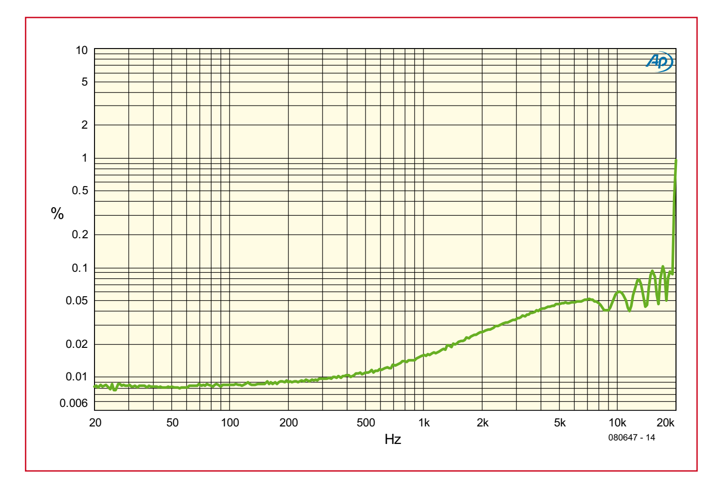



**Figure 6. Distortion measurements.**

The sample Aurel digital wireless audio modules used by Elektor in this article were kindly supplied by P2M (France)

(080647-I)

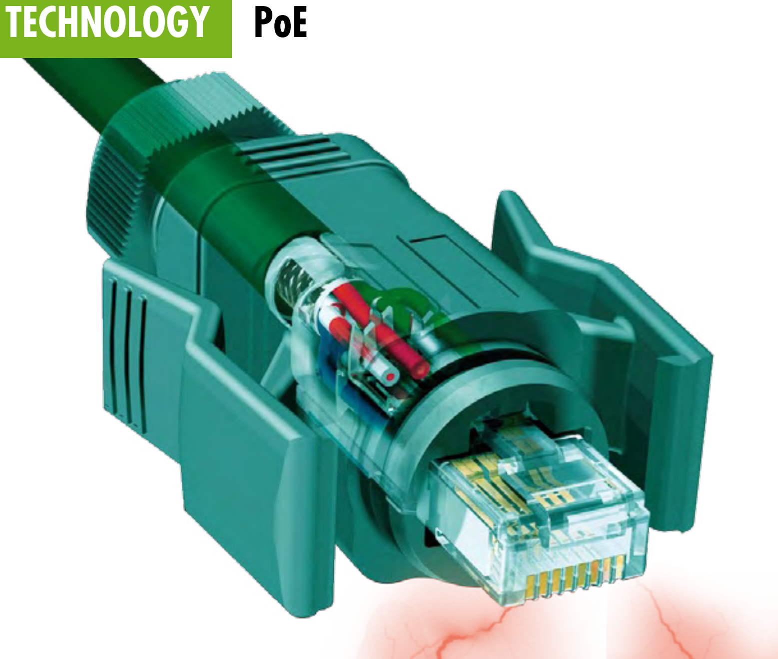
## Internet links

**Aurel:**
www.aurelwireless.com

**UK distributors:**
J&C Components (info@jandccomponents.co.uk); Radio-Tech Limited (sales@radio-modem.com); CHARTLAND Ltd. (chartland@dial.pipx.con).

**US distributor:**
ABACOM (abacom@abacom-tech.com)

**Author's website:**
www.tavernier-c.com



# PoE: Power over Ethernet

Stefan Tauschek (Scantec)

**Providing power to apparatus over network cables has always been usual practice for fixed-line telephones, and now the same capabilities are becoming available on wired Ethernet. The IEEE 802.3af PoE (Power over Ethernet) standard allows up to 13 watts to be supplied and its successor, PoEPlus (802.3at), allows up to 30 watts. In this article we look at how it works in theory and in practice.**

Power over Ethernet (PoE) allows power to be supplied to all kinds of devices, from access points to IP cameras. Although users will be happy to be relieved of the problem of finding a spare mains socket when connecting up their latest gadget, things are not so easy for the manufacturer of networking equipment. A 24-port switch fully fitted out with PoE needs a power supply with a rating of nearly 1 kW. High-efficiency switching supplies and careful power management are thus needed.

**Figure 1.** Power can be supplied via endspan PSEs (PoE-capable switches or hubs) or via midspan PSEs with normal switches or hubs. The connected device which receives power is known as a PD.

## IEEE standard PoE

IEEE standard 802.3af defines PoE. The standard specifies how both data and power are delivered over a network cable (generally Cat 5 or Cat 5e). An extension to the standard, 802.3at, is already being worked on. It will allow for higher power levels, sufficient to supply laptops, video phones and high-power WLAN access points without the need for separate mains adaptors.

In delivering power over a network cable PoE is reminiscent of analogue fixed-line telephone systems (POTS, or Plain Old Telephone System) which provide phantom power to apparatus over the a- and b-wires. PoE allows a modern VoIP telephone to be powered in a similar way, without needing a separate mains supply.

## The problem of thin wires

Delivering electrical power over a Cat 5 Ethernet cable presents some technical difficulties. The conductors used are typically AWG 24 (approximately 0.5 mm diameter) and have a resistance of around 94 Ω per kilometre. The figure is slightly higher than might be expected because the individual twisted conductors in 1 km of cable are slightly more than 1 km long. If we consider the maximum cable run for a single segment of an Ethernet network (100 m) and use four conductors to carry power, we can expect a total loop resistance in the region of 10 Ω. If the connected device needs say 10 W of power at 5 V the current drawn will be 2 A and the cable

will drop 20 V and dissipate an astonishing 40 watts! The conclusion is clear. To reduce losses in the cables we need to use higher voltages at lower currents to send power to the attached client devices, each of which will contain a DC-to-DC converter to reduce the voltage to the required level at a higher current. In the PoE standard the nominal voltage supplied is 48 V (with an acceptable range being 36 V to 57 V) at a maximum of 350 mA. This means the system is covered by the SELV (safety extra-low voltage) regulations [1].

Even at this voltage there is a noticeable voltage drop: 0.35 A times 10 Ω is 3.5 V. The network cable dissipates up to 1.2 W. DC-to-DC converters at both the supply and client end ensure stability of the final supply voltage.

## PoE topology

As Figure 1 shows, a PoE system consists of a source (the PSE, or Power Sourcing Equipment) and a number of sinks (PDs, or Powered Devices). There are two types of PSE: so-called endspan devices and midspan devices. The former are sources of data packets and current, while the latter pass data packets through and add PoE.
Figure 2 shows how the unused pins 4 and 5 (positive) and 7 and 8 (negative) of an RJ45 connector can be used in 10BASE-T and 100BASE-T systems. An alternative is shown in Figure 3, where phantom power is supplied on data pins 1, 2, 3 and 6.

Phantom power exploits the fact that Ethernet connections provide galvanic isolation between pairs of connected devices using a transformer at each end. It is therefore possible to add a DC voltage to the signals using the centre taps of the transformers, without adverse effect on signal quality. This form of PoE is generally preferred as with existing installations it is not always certain that the so-called 'spare pairs' are actually connected in the cables or connectors. In Gigabit Ethernet systems there are no spare pairs, as all eight conductors are used (in four differential pairs) for data transfer.

## PoE operation

At power-up a PSE device must first determine whether any PDs are connected and what their power requirements are, and check that there are no short-circuits in the network. To this end the PoE standard specifies a signalling protocol whereby the necessary information is exchanged at boot time to ensure effective power management.
After reset or power-up the so-called 'signature detection' sequence starts (yellow area in Figure 4). The PSE provides a 0.1 V/µs voltage ramp in the range from 2.7 V to 10 V. By carrying out two impedance measurements it can determine whether a PD is connected. If the detected impedance lies in the range 15 kΩ to 33 kΩ the classification phase begins. If an impedance outside this range is detected, power is disabled on the connection.

The next step is to determine the power classification of the PD. During this phase the PSE raises the voltage into the range 14.5 V to 20.5 V. The PD should draw a 'signature current' which signals its power class to the PSE. The PSE can then determine the PD's power requirement. The 802.3af standard specifies five power classes (see **Table 1**).

When classification is complete the PSE raises the phantom supply voltage to its nominal value of 48 V. The maximum

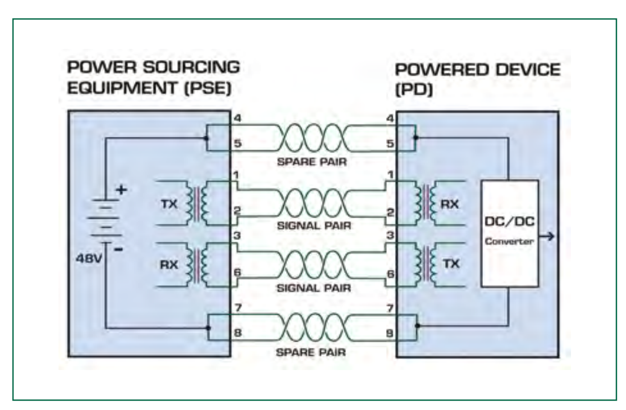



**Figure 2.**
**In a Fast Ethernet system power can be supplied over the two spare conductor pairs.**

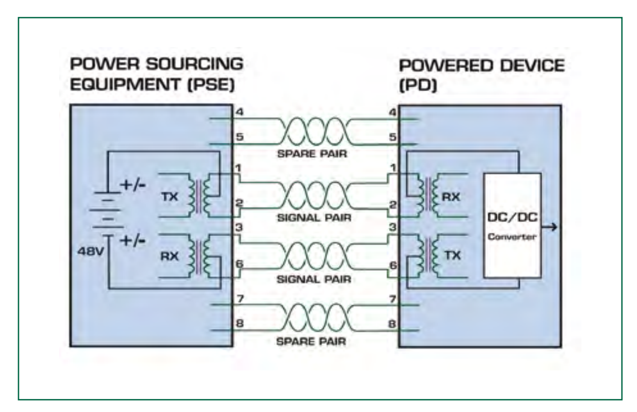



**Figure 3.**
**Phantom power uses the data conductors and hence is also compatible with gigabit Ethernet.**

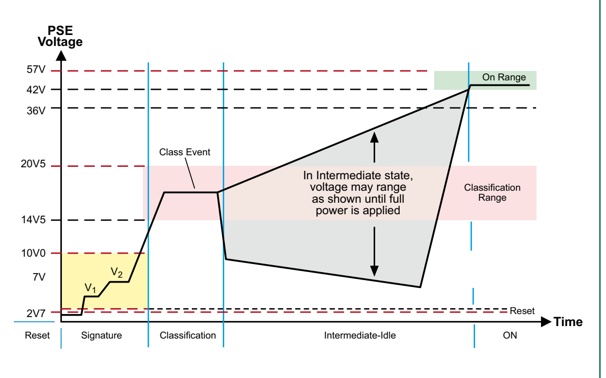



**Figure 4.**
**Signalling protocol for 802.3af PoE.**

**Table 1**
**The 802.3af standard defines four power classes plus a reserved class, which is used for PoEPlus.**

| Class | Use | Signature | PSE power | PD power |
|---|---|---|---|---|
| 0 | standard | < 5.0 mA | ≤ 15.4 | 0.44 W to 12.95 W |
| 1 | optional | 10.5 mA | ≤ 4.0 | 0.44 W to 3.84 W |
| 2 | optional | 18.5 mA | ≤ 7.0 | 3.84 W to 6.49 W |
| 3 | optional | 28.0 mA | ≤ 15.4 | 6.49 W to 12.95 W |
| 4 | reserved | 40.0 mA | reserved | reserved |

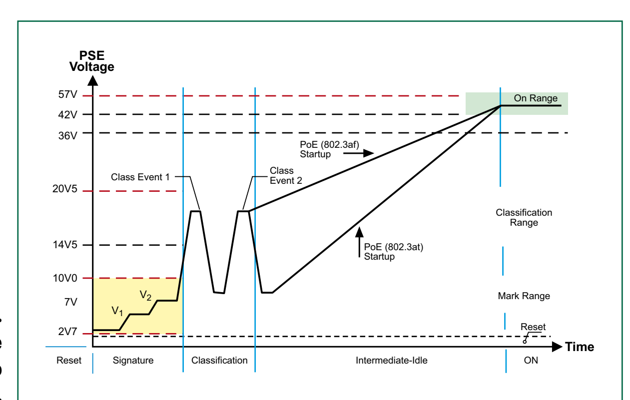



**Figure 5.** The classification phase in 802.at consists of two pulses.

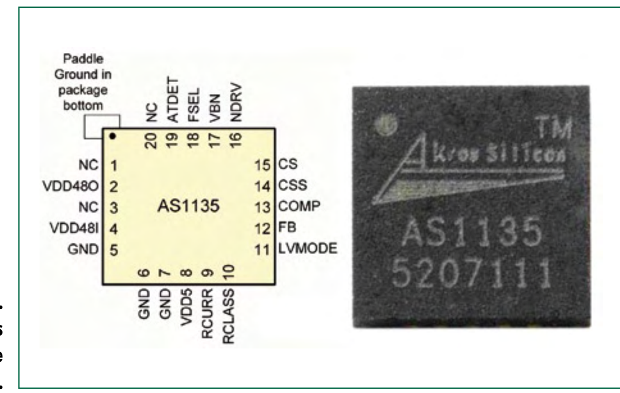



**Figure 6.** The AS1135 controller is available in a 5 mm square QFN package.

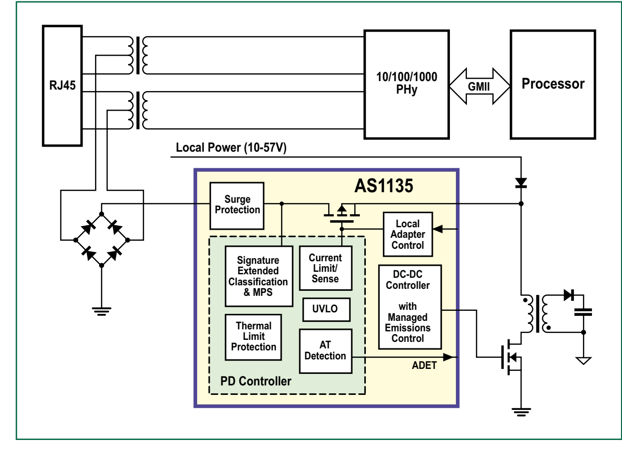



**Figure 7.** Block diagram of a PoE DC-to-DC converter using an AS1135.

losses in the cable are such that at least 37 V appears at the PD at a current of 350 mA, for a total power of 12.95 W.

There is thus a total of three phases: detection, classification, and application of power (operation). There are various timing requirements that must be observed. For example, under PoEPlus, signature pulses can last a maximum of 30 ms and the gap between them can be at most 12 ms.

## More power

The successor to PoE, IEEE 802.3at or PoEPlus or PoEP-lus, is under development. It is backwards compatible with 802.3af and will allow up to 30 W to be delivered to a PD. The standard mandates the use of Cat 5e cabling and the PSE voltage range is raised from between 44 V and 57 V to between 50 V and 57 V. The maximum current is raised to 720 mA from 350 mA and the maximum permissible cable temperature is set at 45 °C.

PSEs designed according to the new standard can be used with 'old' PDs. On the other hand, new PDs can of course not draw the full 30 watts from an old-style PSE. The new parts of the system are accommodated by extending the classification procedure. As **Figure 5** shows, there are now two classification pulses. PDs conforming to PoEPlus must initially identify themselves as class 4 devices. During the extra classification pulse they must then draw a signature current of 40 mA. A PoE standard device will ignore the second pulse, allowing a clear distinction to be made between PoE and PoEPlus devices.

## Practical implementation

Many companies, including Linear Technology, Texas Instruments and National Semiconductor, are already producing chips to support PoE technology. Because of their high level of integration we will look below in greater detail at products from Akros Silicon, a relatively young company.

The AS1113, AS1124, AS1130 and AS1135 are PoE controllers fabricated using a standard high-voltage CMOS process. They are physically small and have a high level of integration. The AS1113 implements the 802.3af standard, delivering up to 13 W of power. The most recent member of the family, the AS1135 (**Figure 6**), is designed for PoEPlus applications and can deliver output powers from 13 W to 30 W. Since the various PoE devices from Akros Silicon are pin-compatible with one another, system manufacturers can lay out a single printed circuit board for both high- and low-power devices, avoiding the need for complete re-designs.

The PoE ICs include a current-mode DC-to-DC converter with soft-start and current limiting functions.

Using suitable external components, flyback, forward or buck configurations can be realised, and both isolated and non-isolated devices are supported.

The AS1135 example circuit has particularly high efficiency thanks to an active rectifier, where the conventional secondary switching diode is replaced by a synchronously-controlled FET. This technique avoids the otherwise inevitable forward voltage drop of 0.5 V or more associated with Schottky diodes, substituting the voltage drop across the very low channel on resistance of a modern MOSFET. This saves up to 0.5 W or even more at higher currents.

## PoEPlus using the AS1135

The design we describe here is based on the Akros Silicon reference design. The AS1135 [2] is the first controller device to support the provisional 802.3at (*Draft 3.0*) standard, which uses a double pulse during the classification phase. It is therefore backwards compatible and can be used as a PD adaptor in power-drawing devices and in PoE-standard PSEs.

The highly-integrated DC-to-DC converter drives an external power switch and monitors the current through the primary winding of a transformer. It provides a soft-start function. The switching frequency can be set using a resistor in the range 100 kHz to 500 kHz: in the example circuit we have selected 350 kHz. The transformers do not need to be made specially: suitable types are available from distributors such as Coilcraft, Halo Electronics and Würth Elektronik.

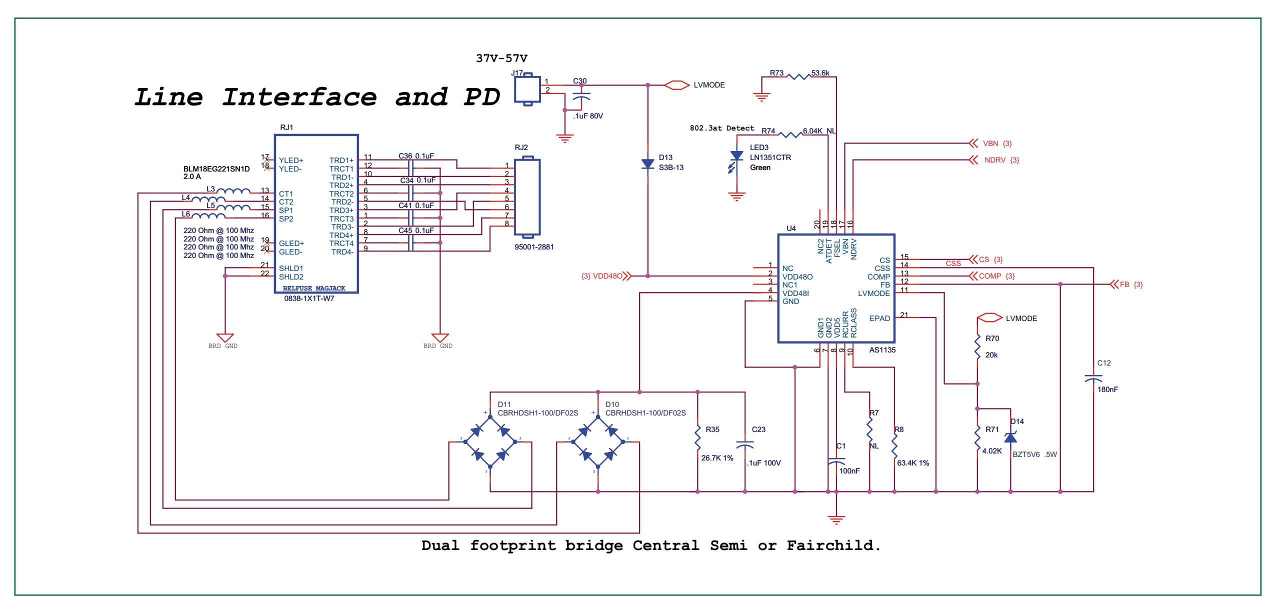



Figure 8. Connecting an AS1135 to the Ethernet cable.

## PD circuit

The Ethernet cable from a switch or midspan is terminated using a Belfuse RJ45 socket/transformer, which supports data rates up to 1 Gbit/s and which is designed for use in PoE applications. As can be seen in **Figure 7**, the centre taps are taken via a bridge rectifier to the voltage input $V_{DD}$48I of the IC. In the practical circuit shown in **Figure 8**, all pairs are used and so two bridge rectifiers are provided. The signature current of 40 mA is set by resistor at $R_{class}$, corresponding to power class 4 and thus also to PoEPlus. The resistor at $R_{curr}$ sets the current limit: the pin being left open circuit corresponds to the maximum value of 900 mA. The feedback pin FB is not used in the isolated buck/boost converter configuration, and so is taken to ground. The capacitor on pin CSS sets the time constant for the soft-start function: 100 nF gives a value of around 2 ms.

Since in practice it is not known in advance whether a device capable of being powered using PoE will actually be used in a network that supports it, devices also need to be able to accept power from an external mains adaptor. This is very straightforward to set up using the Akros controllers. An external voltage between 10 V and 57 V is applied via a diode to pin $V_{DD}$48O and simultaneously via an RC network to LVMODE. This tells the controller that an external supply is available and $V_{DD}$48I is isolated. The DC-to-DC converter, however, remains active.

The voltage regulator circuit proper, shown in **Figure 9**, is rather more complicated. The polarity-protected, rectified voltage from the Ethernet cable is taken from pin $V_{DD}$48O via a pi-filter which protects the LAN signal wires from interference. From there it goes to the primary side of a transformer and thence to the primary switching transistor, which

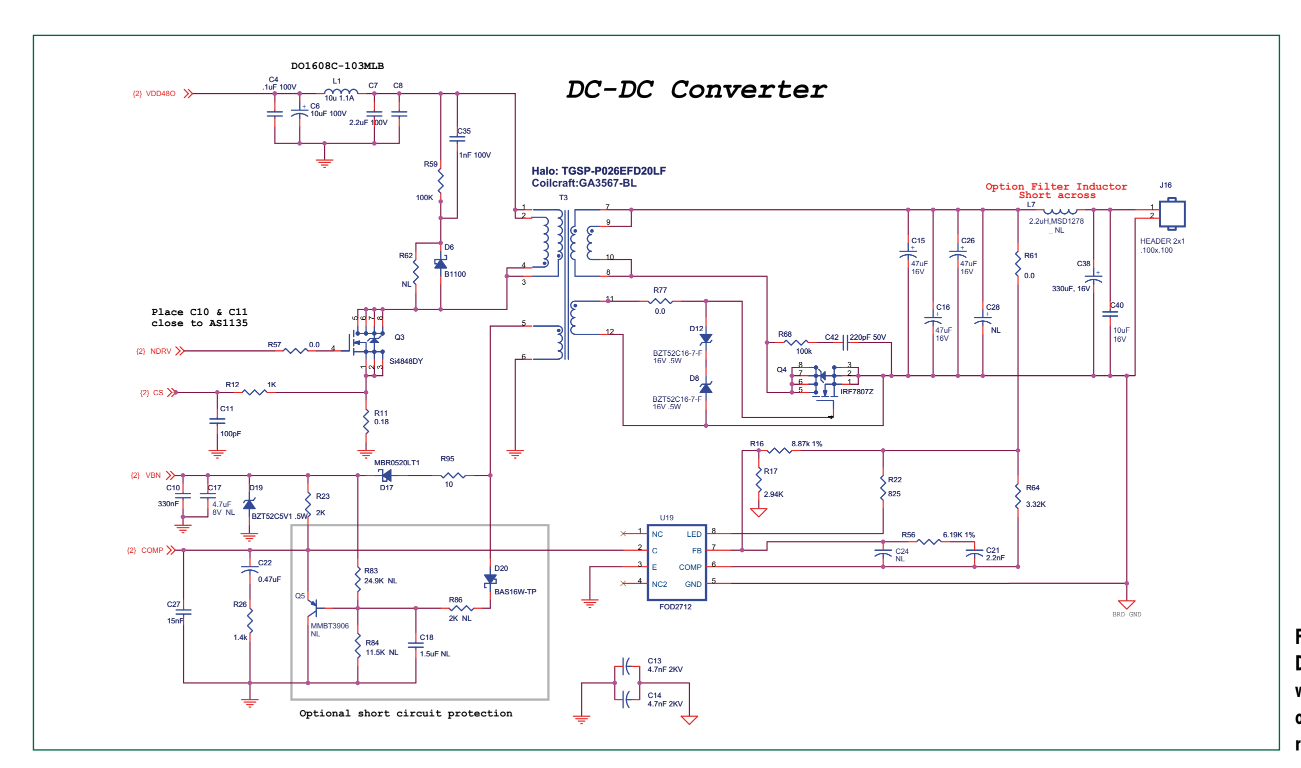



Figure 9. DC-to-DC flyback converter with an output power of 30 W and active rectification.

## About the author



Stefan Tauschek studied electronic engineering, specialising in communications, at the Munich University of Applied Sciences, and worked for several years developing multimedia components, video processing and streaming media technologies.

He is now a technology consultant at Scantec AG, supporting industrial customers in projects involving networking, telecommunications and automation.

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switches to ground. The device used here is a Si4848DY from Vishay, an N-channel MOSFET with an on resistance of around 100 mΩ at a current of 3.5 A. Components R59, R62, C35 and D6 form a snubber network to suppress spikes. Short-circuit protection on the secondary (device) side is provided by a limiting circuit consisting of R83, C18 and Q5. In operation the voltage difference between pins 5 and 6 of the transformer is about 6.5 V. This is sufficient to ensure that transistor Q5 remains firmly off. If there is a short circuit at the output, the AS1135 sets the mark-space ratio of the switching pulses in flyback converter configuration to a minimum and the voltage between pins 5 and 6 falls. Then Q5 starts to conduct and pulls the COMP pin of the AS1135 to ground. This in turn limits the current to about 100 mA for as long as the short-circuit persists.

The Fairchild FOD2712 optocoupler allows the AS1135 to monitor the output voltage. The frequency response of the negative feedback loop can be set using an extra RC network to achieve stable operation with a quick control response and low overshoot.

Figure 10. The reference board from Akros Silicon, ready for operation.

### The future: 60 W

As standard PoE has become more widespread for local area networks, more and more client devices have become able to make use of it. The power limit of 13 W offered by 802.3af was, at the end of the 1990s when the standard was developed, entirely adequate as there were few devices capable of using phantom power and the Cat 3 cable that was generally installed was not electrically suitable for providing more.

Since then things have changed: now Cat 5 and Cat 5e cable are ubiquitous in network installations, offering higher bandwidth and lower resistance. Also, there has been a sharp growth in demand for devices such as VoIP telephones, IP cameras and wireless access points, which can all benefit from PoE.

PoEPlus supports these developments by doubling the available power to 30 W. But, adding to the performance also provokes the desire: and so the IEEE 802.3at working group is now looking at how power levels of up to 60 W can be delivered using Cat 5e cable.

### More power using four conductor pairs

Since the PoEPlus specification stretches the physical capacity of Cat 5e cabling and connectors to the limit, a further doubling in power can only be achieved by using greater parallelisation. The IEEE working group looking at this problem is therefore intending to consider delivering electrical power over all four Ethernet cable pairs rather than just two. That would give a direct doubling of power capacity to 60 W. However, the working group appears to have suffered a case of cold feet, as in *Draft 3*, dated March 2008, a power limit of 24 W for two pairs was proposed. There is considerable concern over cable overheating, particularly in large networks with thick bundles of cables, which could lead to damage to the cable or even to fires. Whatever variation wins through, it is certain that PoEPlus in its final form will be specified for power levels in excess of 30 W, divided over four pairs of conductors.

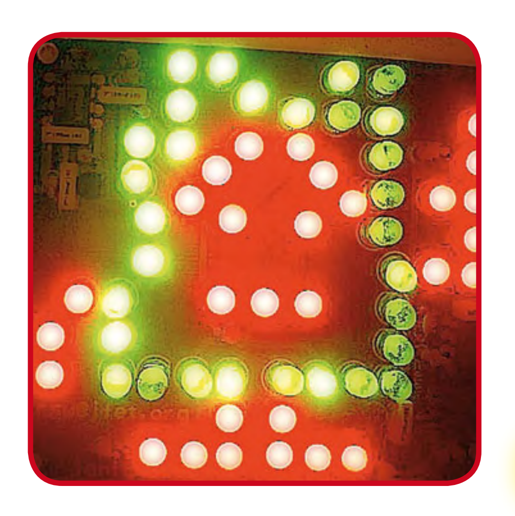
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## Internet Links

**[1] SELV:**
http://en.wikipedia.org/wiki/Extra-low_voltage

**[2] AS1135 product page:**
http://www.akrossilicon.com/products/as1135.html


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# i-TRIXX

## Assorted small circuits in a free 24-page section in Elektor's December 2008 edition

For the third year round, Elektor editors and designers have compiled a varied collection of simple but useful and sometimes even charming electronic circuits that you can build yourself, eliminating, hopefully, any cause to complain about a general lack of simple stuff in the magazine. The 2006 and 2007 i-TRIXX supplements were generally well received in terms of their classroom merit and technical content, both by old hands at electronics and newcomers to the Elektor publication, from all over the globe. The success story is continued this year.

Although the present i-TRIXX collection is again aimed at those of you starting out in electronics or on a modest budget & scavenging components from the junk box, we know that the circuits presented also have an appeal if you just want to slap something up in an afternoon or so. All projects are based on easy to obtain components or items normally thrown away as useless just because you're told they are not "state of the art", whatever that means.

An i-TRIXX project is never complicated, big or difficult to understand, we hope! Plus, it can be soldered together in a spare hour or so. These free 24 pages contain a large selection of these types of circuits pulled from the Elektor lab and from our large circle of free-lance contributing authors. If you would like to contribute to next year's 'dose', please let me know.

Happy reading & soldering (all RoHs compliant, of course!)

Jan Buiting
Editor

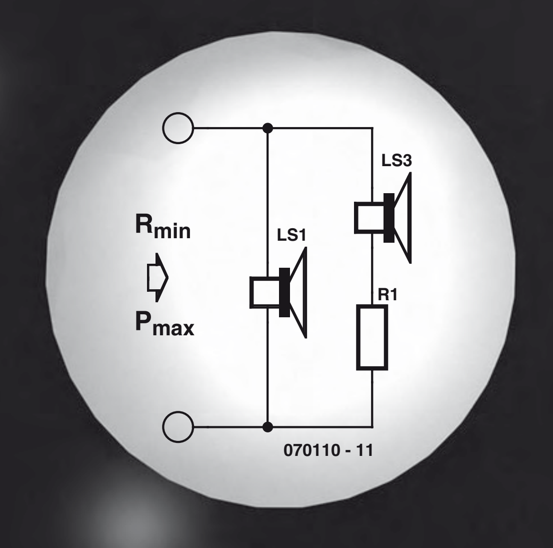



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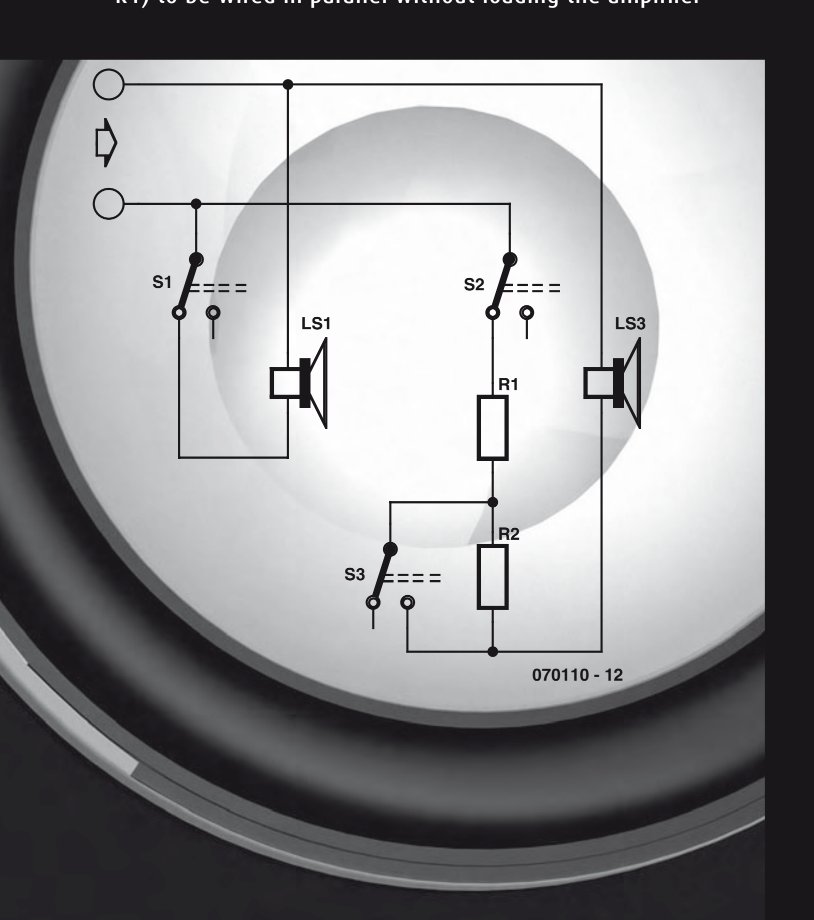
# Add more speakers

*Design: Franz-Peter Zantis (Germany)*

The chances are that you only have one socket on the back of your mini HiFi to connect the speakers. Wiring an extra set of speakers in parallel to the originals may damage the amplifier output stage if the resulting load impedance is too small. Extending the sound of your HiFi into another room (e.g. bedroom or study) may not be entirely unproblematic.




For clarity the modification to only one of the stereo channels is described here, simply repeat the process to make extensions for both the left and right channel speakers.
It may be the case that you have a mini HiFi without any speakers or you want to use the (usually low quality) existing speakers as extension speakers. Firstly check the amplifier rating which should be either in the amplifier handbook or printed on the back of the amplifier. Choose a set of main speakers (LS1) which have an impedance greater than the minimum load that the amplifier can handle. This minimum load may for example be 4 Ω in which case 6 Ω or better still 8 Ω speakers would be a good choice. Amplifiers with a minimum load of 6 Ω would need 8 Ω or better 12 Ω speakers. Most amplifiers will have enough power in reserve to offset the reduction in volume. The loudspeaker sensitivity with respect to the volume setting now seems to have an approximately logarithmic characteristic rather than linear.
For the extension speaker LS3 make sure its impedance is equal to or greater than the main speaker LS1.
From the diagram you can see that the principle is really simple, now that the main speakers have an impedance greater than the minimum value required by the amplifier it allows an extension speaker (with a suitable series resistor R1) to be wired in parallel without loading the amplifier too much. The minimum value of series resistor R1 can be calculated:




$$R1 = (R_{min} \times Z_{LS1} + R_{min} \times Z_{LS3} - Z_{LS1} \times Z_{LS3}) / (Z_{LS1} - R_{min})$$

The value $R_{min}$ is the minimum load that the amplifier can handle (check the amplifier specification).

The power rating ($P_{R1}$) of resistor R1 can now be calculated:

$$P_{R1} = (P_{max} \times R1) / ((Z_{LS3} + R1)^2 : Z_{LS1} + Z_{LS1} \times R1)$$

Power dissipated in the extension speaker will be:

$$P_{LS3} = (P_{max} \times Z_{LS3}) / ((Z_{LS3} + R1)^2 / Z_{LS1} + Z_{LS1} \times R1)$$

Power dissipated in the main speaker will be:

$$P_{LS1} = P_{max} / (1 + Z_{LS1} / (Z_{LS3} + R1))$$

A typical example giving $R_{min}$ = 4 Ω, $P_{max}$ = 50 W, $Z_{LS1}$ = 8 Ω and $Z_{LS3}$ = 8 Ω can be worked out in your head. R1 is not needed i.e. it has a value of 0 Ω and power is divided equally between LS1 and LS3, each dissipating 25 W. When however $Z_{LS1}$ has a value of 6 Ω, then R1 = 4 Ω, $P_{LS1}$ = 33.3 W, $P_{LS3}$ = 11.1 W and $P_{R1}$ = 5.6 W. Ensure that the power rating of R1 is bigger than this figure.

Semiconductor devices such as triacs and thyristors are taking over more and more tasks from normal relays. However, this doesn't mean that you can't build interesting or useful circuits with normal relays.

# Switching with relays

*Design: Thomas Scarborough (South Africa)*

There are many practical applications in which it is necessary to switch a lamp or other device on and off by using a short pulse or briefly pressing a button. For example, this method (which is also called toggle operation) is used in the staircases of many public buildings for switching the hall lights using relays with built-in timers, such as the German Eltako series. Relays are a perfect choice for this application. A relay with two separate changeover contacts is well suited to this sort of job. Many relays are available in encapsulated form, which provides better protection against corrosion and soiling of the sensitive contacts. In principle, it does not matter which product you use as long as the relay is designed to handle the intended task. The contacts and the coil must both be specified for the currents and voltages used in the application.

Here one of the two changeover contacts (RLA1b) switches a load (such as a lamp, machine or motor) on and off. The second changeover contact (RLA1a) is used to latch the relay. This means that the relay remains actuated after pushbutton switch S1 (a normally-open switch) is released. When S1 is pressed, RLA1a closes and shorts out S1. As a result, current continues to flow through the relay after the button is released. A brief interruption is all it takes to stop the current, and this is provided by S2, a normally-closed switch.

Naturally, an external switch such as the contacts of a motion detector can be connected in place of S1 or in parallel with it. If you wish, you can also use a separate supply voltage ('optional switching') to energise the relay coil in parallel with the usual control arrangement.

## Gag circuit

We conclude with small story from the author's experience. As a youth, he once hid a circuit like this in a rubbish container. The idea was that when the lid was opened, it should send a current through the filament of an incandescent lamp (with the glass removed) to light a string of small firecrackers. In order to attract potential victims, Thomas glued a piece of paper to the container with a note saying that the lid should not be opened under any circumstances. When his father came home from work in the evening, he asked with some surprise what the note on the container was supposed to mean, since he had opened the lid and nothing had happened. As his son thought that his circuit must have failed to work, he went straight to the rubbish container, opened it, and found himself in the midst of a hail of exploding firecrackers. As it happened, his father had seen him putting together his firecracker alarm earlier that morning.

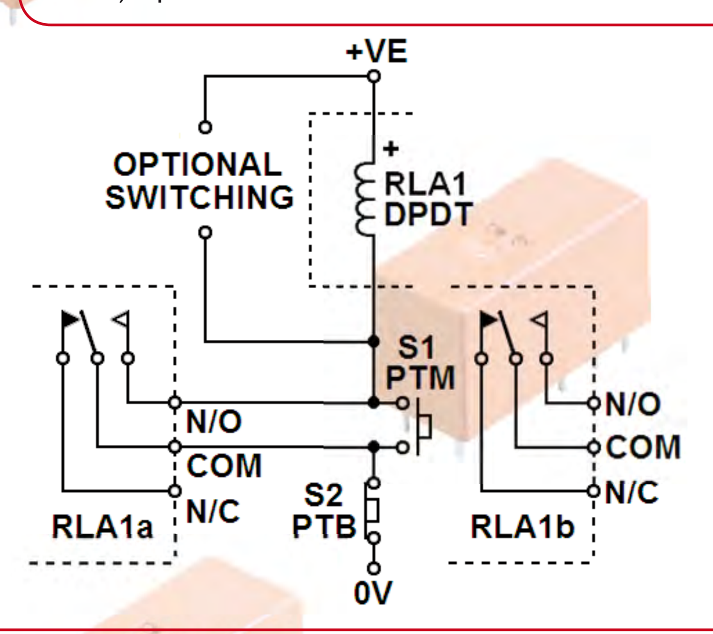
THERE ARE A VARIETY OF APPLICATIONS FOR THIS CIRCUIT, SUCH AS THE ONES DESCRIBED BELOW:

### SAFETY MAINS SWITCH

Picture the following situation: while a table saw is running in a carpentry shop, there is a sudden power failure. As a result, everything stops working, and everyone takes a break. If the shop foreman forgets to switch off the machine, it will unexpectedly start up again 'on its own' when the power is restored. This can be quite hazardous. If the above circuit is fitted to the table saw, this cannot happen. It will remain in the 'off' state even after power is restored, and it can only be started again by pressing switch S1 again. For a truly professional solution, the circuit can be built using a large green pushbutton for S1 and a large red pushbutton for S2 (available in the better class of home-improvement shops).

### THEFT ALARM

For this application, S1 is replaced by a switch with normally-closed contacts and the object to be protected (such as a PC) is placed on top of the switch so that its weight actuates the switch. If the object is removed, the switch closes and a siren is activated by RLA1b, and it continues to sound until switch S2 (in a concealed location) is pressed.




### TWO-WHEELER ALARM

Contact switches respond to motion. If a contact switch is used for S1 and the entire arrangement is built into a moped, scooter or motorcycle, the alarm will be triggered as soon as a thief moves the vehicle.

### INTRUSION ALARM

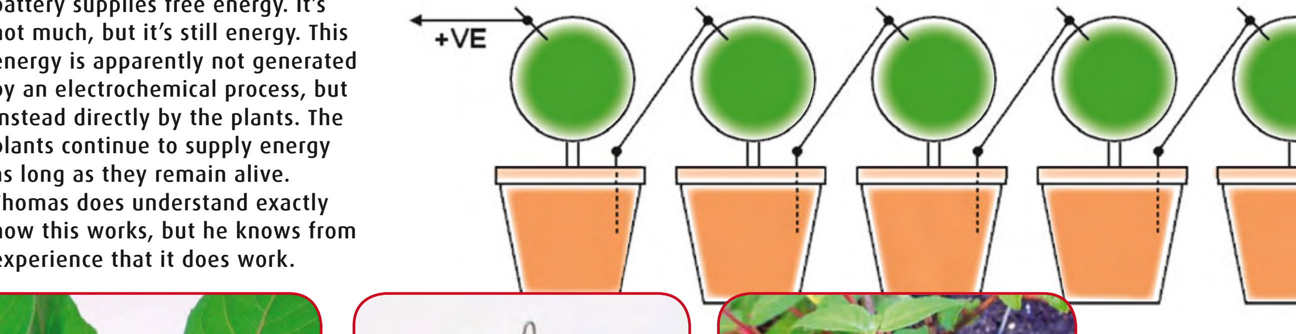
If S1 is replaced by a door switch or window switch, the circuit can be used as the core of a home intrusion alarm system. With this version of the circuit, as many switches as desired can be connected in parallel in place of S1. A key switch can be used for S2 in this case, so that the siren triggered in case of an alarm can only be switched off by the homeowner.

# Potted-plant battery

*Design: Thomas Scarborough (South Africa)*

As incredible as it may sound, the author has recently been powering a LCD clock module from a set of potted plants. A 'biological power station' of this sort may remind you of the well-known apple and lemon batteries, where two electrodes made from different metals are stuck into a piece of fruit to form a sort of simple galvanic cell. However, in this case the cells of the battery draw their energy directly from the plants, rather than from an electrochemical process. Does this means that the plants are actually generating the electricity?

There's no question that the plant battery supplies free energy. It's not much, but it's still energy. This energy is apparently not generated by an electrochemical process, but instead directly by the plants. The plants continue to supply energy as long as they remain alive. Thomas does understand exactly how this works, but he knows from experience that it does work.











A potential difference of approximately 0.4 V can be measured between the plant and the soil it grows in. This voltage source can supply a power of approximately 0.8 microwatt, regardless of whether the plant is a small houseplant or a large bush.
Of course, this is far too little power for most applications, but it is enough to operate a simple LCD clock module. Of course, this requires connecting several plants in separate pots in series to form a battery. The series connection would not work if the plants were all in the same pot, since in that case the pot soil shared by the plants would act as a sort of 'common ground' in the literal sense. The pots must also be located on an electrically non-conductive surface. The schematic diagram shows how five potted plants can be connected in series to form a biological battery with five cells.

Five or six plants are enough to power a 1.5-V LCD clock or a simple LCD thermometer. Just like a normal battery cell, each plant has two terminals. The first terminal is located on a branch of the plant. This terminal can be formed by sticking a needle or small pin through a branch of the plant and connecting an alligator clip to it. The other terminal is in contact with the pot soil.

A relatively long metal rod stuck into the soil, also connected with an alligator clip, is sufficient for this purpose. All of this is shown quite clearly in the photos.
Five or six potted plants can be connected together in this manner to form a series circuit as shown in the schematic diagram. Now an electronic device, such as an LCD clock with very low power consumption, can be connected to the outer terminals of this battery. The positive terminal of the clock is connected to a free branch of the first plant in the series, while the negative terminal is connected to the soil of the last plant in the series.

## HOW DOES IT WORK?

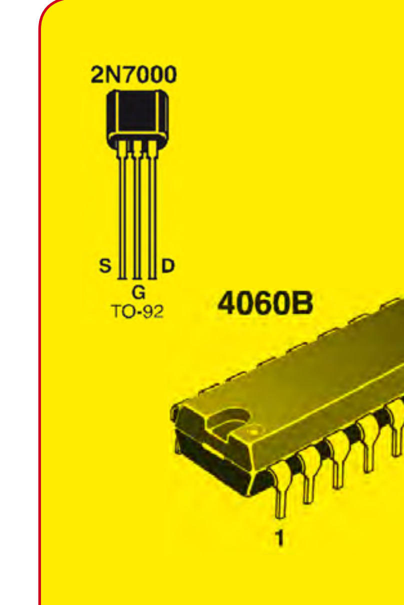
The operating principle of the potted-plant battery is currently the subject of vigorous discussion in numerous forums. We don't want to get involved in these discussions here, but we can present a few facts mustered by the author to counter the arguments of his opponents:

1. The objection that this is simply an ordinary electrochemical reaction can be proven false by using gold-plated electrodes, since gold is a noble metal that does not participate in electrochemical reactions. Nevertheless, the plant battery produces electricity if gold-plated electrodes are used.

2. It has been suggested that that the energy comes from the reception of radio signals. This theory can be disproved by the fact that the battery also works when it is inside a Faraday cage.

3. A plant expert has suggested that the electricity is generated by the DNA of the plant. The author regards this as the most plausible explanation.

*(Discussion closed.)*





# Scarecrow

*Design: Thomas Scarborough (South Africa)*

Take a look in any back garden and you are likely to see evidence of the affection we hold for garden birds. Bird feeders and bird baths draw them into the garden in the depths of winter when their usual foodstuffs have long since fallen from the trees and lie frozen in the soil. Even in the summer months bird tables are scattered with old crusts and sunflower seeds to provide a snack for the summer visitors and some people (probably falsely) interpret birdsong as some sort of a thank you from our feathered friends. Anyone who tends a fruit and vegetable garden may have a slightly less welcoming attitude toward them; in the sowing season they eat seeds and nip off the tips of new shoots. At harvest time they take fruit that we were hoping to eat ourselves.

(c)Tomo.yun (http://www.yunphoto.net/en/)

As any hobby gardener will tell you, some form of scarecrow can be useful at certain times of the year to protect the crops. You sometimes see a traditional scarecrow stuffed with straw and wearing last years cast-offs standing in the middle of a farmer's field. You will probably also have noticed that after a few days the crows find that this new structure makes a useful lookout post where they can perch and contemplate the breakfast laid out before them. No matter how closely the scarecrow may resemble Ozzy Osbourne, birds quickly learn that static structures pose no threat. A much more effective strategy is to use sound energy. The sudden sound of a shotgun will set all birds in earshot up into the air, and many commercial bird scarers use this effect.

The author has suggested this very simple circuit which periodically produces a loud sound to scare birds. The design consumes very little power and uses a common integrated circuit and a piezo sounder. Despite its simplicity, field trials have shown that the device is effective: birds simply flew away when the unit was switched on. After some time the birds did however return, it seems like they eventually become accustomed to almost any disturbance. Anyone living close to a vineyard will know that the farmer only sets out bird scarers as the grapes begin to ripen so that by the time the birds have become tolerant of the noise most of the crop will already have been harvested.

The heart of the circuit is a CMOS counter type 4060B (IC1). This chip contains a clock generator circuit which only requires two external components R1 and C1 to set the frequency of oscillation. The clock is connected internally to a 14-stage binary counter with each stage dividing the frequency of the previous stage by two. This circuit uses outputs Q4 and Q14 giving division ratios of $2^4$ (= 16) and $2^{14}$ (= 16,384). With the values given the output signal from Q14 is around 1 Hz. This frequency is not audible but is used here to turn TR1 and with it the piezo sounder on and off. The circuit periodically produces a loud screech. If necessary the piezo sounder X1 (the type without any internal electronics) can be replaced by a small piezo tweeter unit to increase the sound level.

The whole circuit can be powered by primary cells but if the unit is going to be used for longer than about one week it is better to use a high capacity rechargeable battery. The circuit can also be expanded by adding a Light Dependent Resistor (LDR) so that it turns off at night. Remove the connection to ground on pin 12 and connect instead an LDR between pin 12 and ground. Connect a 10 kΩ (or thereabouts) trimmer between +12 V and pin 12, now adjust the trimmer so that the circuit shuts down as evening approaches.

# Acoustic finder for model aircraft

*(Elektor Labs)*

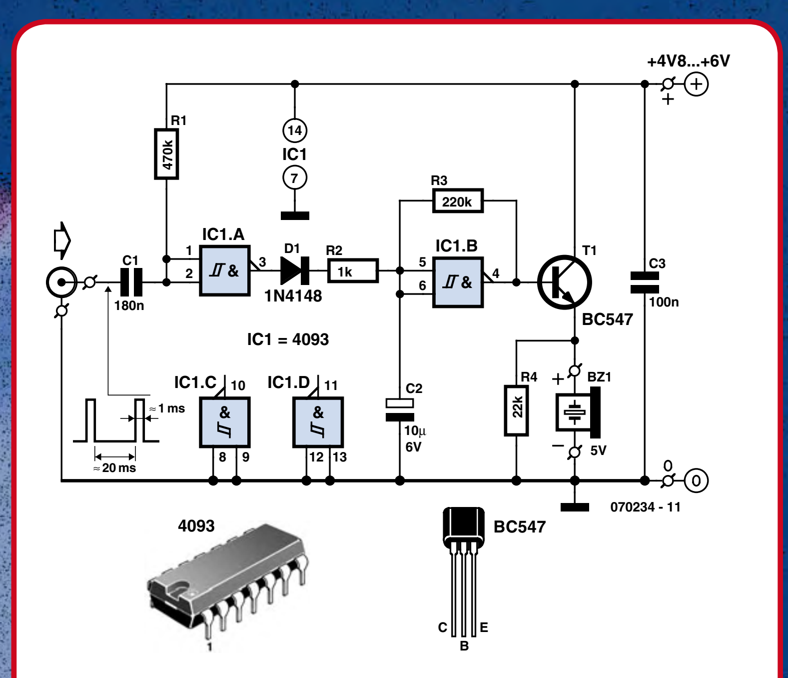
As long as you are in control and it's not too windy then flying model aircraft can be great fun. What happens though when, for some reason the model stops responding to you signals and sets off on its own into the wild blue yonder? Panic breaks out, one thing you can be sure of is that it will eventually come down, the only question is where? (and in how many pieces?) A minor technical glitch can mean that you spend the next few hours scrabbling through hedges, wading across bogs, being chased by dogs and climbing trees in search of the model. Who said that flying model aircraft was a sedentary pastime? Maybe you should be using more of your other senses rather than just relying on your eyes to track down the wayward model. This circuit may be of some assistance...

When you think of all the time, money and energy that you have invested in building your model it would be almost negligent not to take the precaution of adding this very simple circuit to the model's electrics. The operating principle is very simple; as long as the receiver is picking up a signal from the transmitter the circuit remains quiet but when the signal disappears for whatever reason it starts to make a loud beeping sound. The loss of signal may be due to the model flying beyond the transmitter range, a temporary electrical fault or the receiver battery voltage dropping too low. When the search is underway an acoustic signal has the advantage that it can be heard from a great distance and is very easy to locate even if the model has come down behind a bush or in a tree.

The circuit is simpler than it looks. input signal is provided by one of the servo outputs on the receiver. When the servo impulses stop IC1.A no longer charges C2 via D1 and R2. After a short while IC1.B begins to oscillate on and off at a low frequency turning the piezo beeper Bz1 rhythmically on and That really is all there is to it. The inputs of unused gates IC1.C and IC1.D are tied ground to ensure that they do not oscillate and draw unnecessary current. (Both outputs of these gates will therefore be 'high').

The circuit can be powered from the receiver battery pack; it only takes a few µA in normal use when the beeper is not sounding. If the model flies off because the battery pack voltage has sunk too low it will not pose a problem for this circuit. It consumes very little current and will carry on beeping for a long time after the receiver stops working, until the batteries are almost completely flat. It is possible to power the circuit from its own battery pack but you would also need a double-pole on/off switch to switch the receiver and alarm together. Otherwise with separate on/off switches you may forget to turn the alarm back on again the next time you fly.

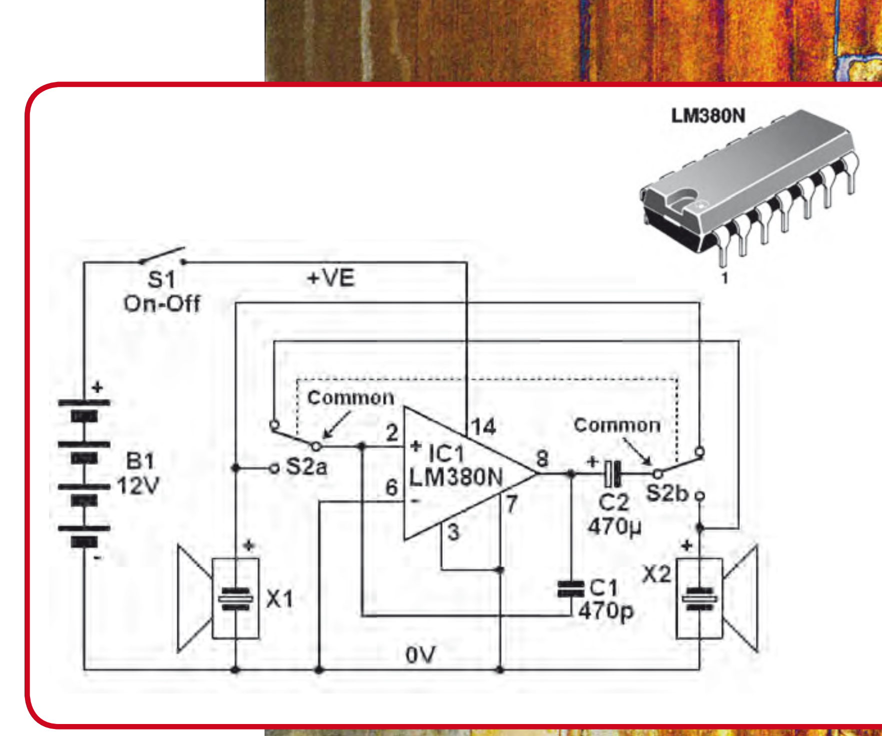
The circuit is so simple and small that it can be built on a small piece of perforated prototyping board. Once it has been constructed, wired-up to the receiver and switched on it can be tested simply by checking that the beeping starts shortly after the transmitter is turned off. For peace of mind it makes sense to perform this check before the model is released. Next time you visit the flying field you can relax a bit more knowing that if your model does head off on its own you stand a better chance of recovering it, unless of course it's taken a dive into a lake...



# An intercom using six components

*Design: Thomas Scarborough (South Africa)*

Many electrical transducers have reversible properties: spin the shaft of an electric motor and it becomes a generator, connect a loudspeaker to the input of an amplifier and it works as a microphone. With this last example in mind it is possible to build a super simple intercom that can also be used as a baby monitor. Two piezo loudspeakers are used here as both microphone and loudspeaker, giving a total of six components for the complete circuit.




As can be witnessed from the circuit diagram the intercom does indeed contain very few components. The circuit is sensitive enough to pick up speech and any other background noise at a distance of a few metres from the microphone. The unit uses a power opamp fitted in the master unit to boost the signal, giving a maximum output power of around 0.5 W. Control of the intercom conforms the master-slave principle; the master site operator has total control over the system from switch on to talk/listen control. The remote site consists of just a simple enclosure to house the piezo loudspeaker and is connected to the master unit using two-core cable. The design is simple but quite versatile and is suitable for many applications ranging from house intercom to baby monitor.

Ignoring the power supply and the on/off switch S1 the complete circuit uses just six components. The two-pole send/listen switch S2 simply reverses the positions of X1 and X2 in the circuit.  For this reason it is important that the transducers are both of the same type. Two moving-coil loudspeakers can also be used in the same basic configuration but it would be necessary to include an impedance transformer at the input to match the opamp input to the (lower) microphone impedance. The piezo transducers used here have a much higher impedance and do not need a transformer which helps keeps the component count down to an absolute minimum.

Signal amplification is provided by the power opamp type LM380N (IC1). With S2 in the position shown in the diagram X2 acts as the microphone and X1 as the speaker. Operating the switch swaps the function of X1 and X2. The switches together with one of the piezo speakers (X1 or X2) are fitted into the master enclosure while the other speaker is fitted at the remote site (front door, garden shed, nursery etc.). A two core cable is all that is needed between the two units.
Both X1 and X2 should be the same type of speaker. The 2-inch tweeter type KSN1020A from Motorola is a good choice here but any similar piezo tweeter would also be suitable. It is important not to use a conventional low-impedance midrange or bass speaker fitted with a coil and magnet. During testing the circuit proved to be quite sensitive; if both speakers are in the same room you will hear the unmistakable screech of acoustic feedback. It is better to put the speakers in different rooms or alternatively for the purposes of testing only, the circuit sensitivity can be reduced by changing the value of C1.

In operation the circuit consumes around 12 mA so a 12 V stabilised mains adapter is an ideal power source but batteries could also be used and would give a reasonable life expectancy if the unit were not in continuous operation.



# Schrödinger's egg

*Design: Rob Reilink (The Netherlands)*

Boiling an egg to give the correct yoke consistency is clearly a very serious business. Everyone has their own preference and it's a sure indicator of a bad day ahead when your breakfast egg turns out to be over or under cooked. Empires have crumbled, marriages failed and banking institutions brought to their knees all for the want of a perfectly cooked egg. OK so maybe we are guilty of over-egging the pudding slightly but the 'doneness' of a boiled egg is difficult to gauge, other foodstuffs are not so secretive; they change colour or yield to the prodding of a knife when they are cooked but a boiled egg just sits there in the pan gently bouncing up and down... A bit like Schrödinger's cat experiment we cannot know the state of the contents until the box/shell is cracked open. Unlike the fate of Schrödinger's cat we can predict the outcome by measuring cooking time. Providing the other variables (egg size, initial egg temperature) are constant measuring the cooking time should produce consistent results.

Kitchen timers come in all shapes and sizes the design here emulates the old clockwork wind-up versions with a pointer indicating the time left. Two pushbuttons are used to set the timed period, indicated by the number of LEDs illuminated. As the timer progresses fewer LEDs are illuminated until at the end of the timed period they all go out, indicating that the egg is perfectly cooked.

Thinking about how the circuit could be implemented you would probably begin with some digital timer/counter to provide an accurate time base and then add a few gates and drivers for the LEDs. You may even want to simplify the hardware more by using a microcontroller. Over the years we have seen many similar designs that have gone down this route but maybe there is an alternative solution?

As demonstrated here and using very few components we can also approach the problem from an analogue direction. A repeatable time base is produced by measuring the time it takes for the voltage in an RC network to decay.

The graph plot illustrates what happens when a charged capacitor C is discharged through a resistor R. The voltage does not fall linearly with time but instead traces a curve corresponding to the exponential function.

47,75mm

72,63mm

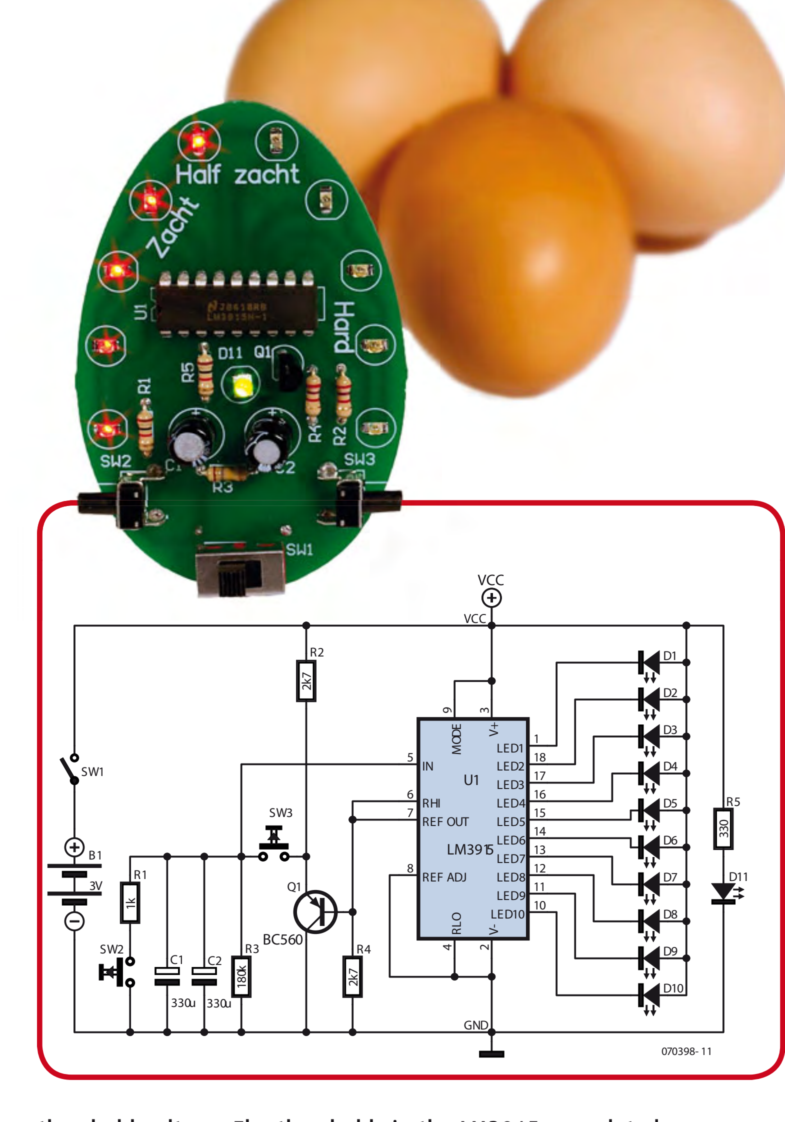
Medium

Soft

Hard

U1 R5 D11 Q1 R1 R4 R2 SW2 C1 C2 SW3 R3 SW1

If we were to set voltage thresholds every 0.5 V and measure how long it takes for the voltage to fall 0.5 V it is clear that in the first time period would be shorter than the second which in turn would be shorter than the third etc, not exactly ideal for a time base. The answer to this problem of non linearity is to use an LM3915 IC. This device is a dot/bar display driver for 10 LEDs. The input voltage level is connected internally to 10 comparators each with a different




threshold voltage. The thresholds in the LM3915 are related exponentially so that they compensate for the discharge curve. The time period between each LED going out is now equal.

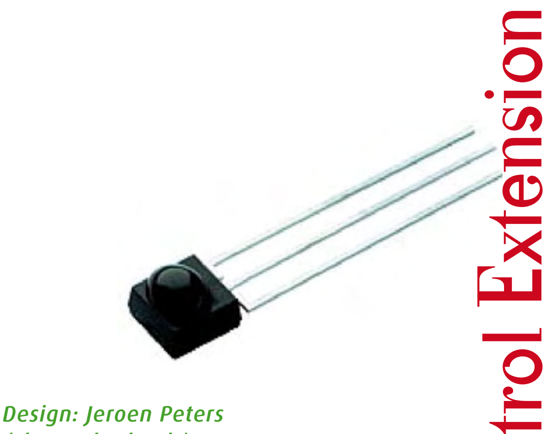
The RC network is made up from C1/C2 in parallel and R3. Two small capacitors in parallel are used here because they take up less space than a single larger capacity capacitor. Pushbuttons SW2 and SW3 are used for setting the time; a press on SW3 extends the time while a press on SW2 reduces the time. Once the desired number of LEDs are lit the buttons are released and the timer runs.

Transistor Q1 limits the voltage on C1/C2, without this measure the capacitor would charge up to the supply voltage and the first time period would be very long. Q1 limits the voltage to approximately 0.6 V above the internal reference voltage (Pin 7 of U1). R4 reduces the current drawn from the reference to 0.5 mA. The LED brightness is also defined by the current drawn from the reference voltage.

Using the layout diagrams given here it is possible to make your own PCB. The images can be transferred to a transparent film ensuring that the finished PCB outline measures 72.6 x 47.8 mm. A .pdf file for the layout can also be downloaded from the corresponding page of the Elektor website, just click on 'Layout' to open the file in Adobe Reader. Armed with a copy of the layout on film you should be able to get the PCB made up in an electronic workshop or PCB manufacturers assuming you do not want the bother of making it yourself. Construction can begin by first fitting the resistors then the capacitors followed by the LEDs and transistor. An 18-way socket can now be mounted to take the IC and lastly fit the pushbuttons and then on the back of the PCB fit the battery holder for the two AAA cells.

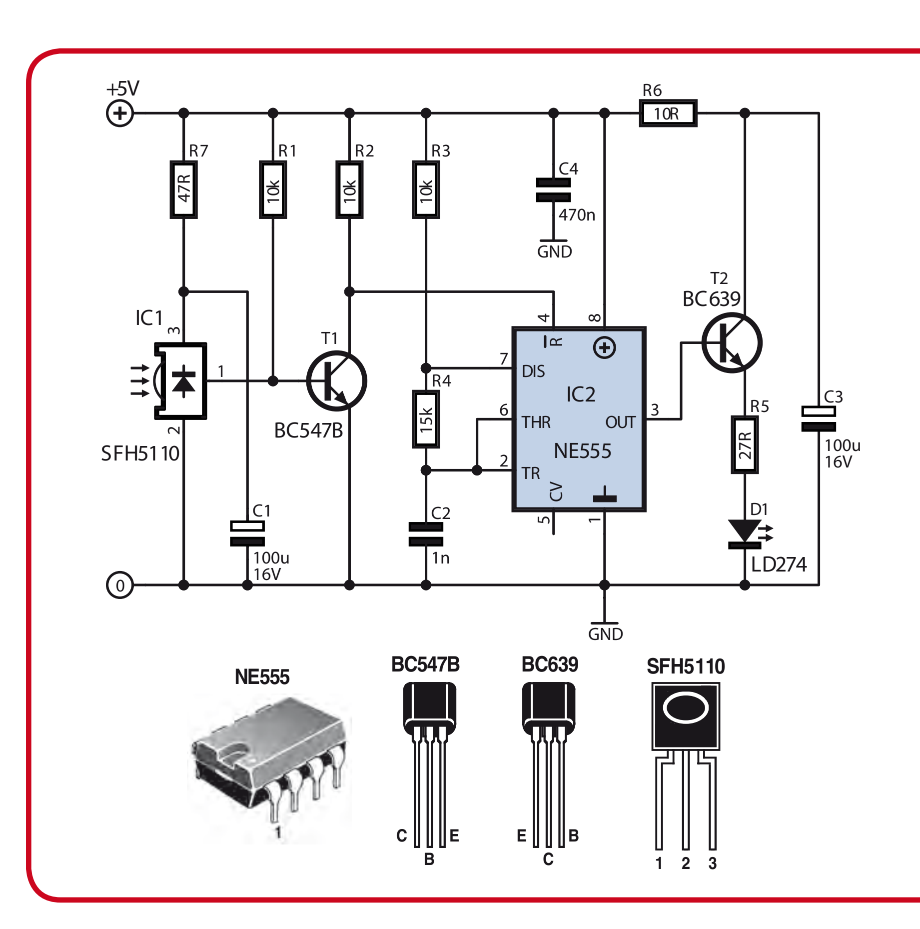
You can experiment with the values of C1/C2 and R3 to alter the maximum timing period.

# Remote Control Extension



*Design: Jeroen Peters*
*(The Netherlands)*

Don't worry — we're not planning to reinvent the cable remote control units used in the 1960s. You can continue to use your stable of IR remote controls (a different one for every imaginable device), and using infrared remote control will be even more convenient than before. A normal remote control unit is helpless if the distance is too great or the device to be controlled is in a different room (or worse yet, concealed in a cupboard). We can change that.




In brief terms, the operating principle of the solution presented here is that you place an IR receiver in a location where it is readily visible to your IR remote control unit. The received signal, in electrical form, is processed and sent further on its way via an IR transmitter LED (and a length of cable if necessary). This way you can not only increase the range, but also magically operate devices 'around the corner' under remote control. You can also turn down the music in the living room while the food is being served in the dining room, and much more.

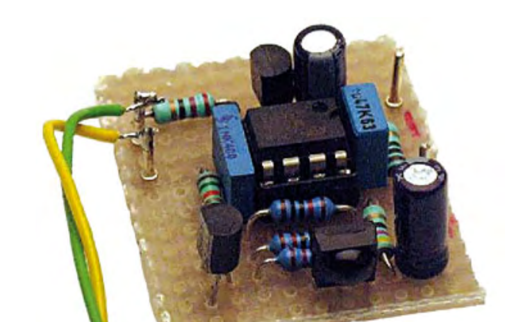
With regard to IR remote control, you should be aware that there is no such thing as a single operating principle – instead, there is a host of signal types, modulation scheme and codes. Every manufacturer, be it Sony, Philips, Sharp or Panasonic, thinks it has to define its own standard. The only common factor is the use of pulsed IR light. In other words, the signals are transmitted as a series of short or long pulses of light at specific base frequency. The pulse widths are in the range of a few microseconds. Using modulated IR light provides better noise immunity with respect to sunlight and light from household lamps. The modulation frequency is typically in the range of 30 to 45 kHz. For the sake of simplicity, you can use a receiver with a typical average value of 36 KHz, since the receiver modules are not that highly discriminating.

The Osram SFH5110-36 (IC1) is a fully integrated IR receiver (see photo) that operates at 36 kHz and generates pulse signals from the received IR light. ICs of this type are available for a number of other frequencies, but experiments have shown that most remote control units also work with the 36-kHz version. Nevertheless, you can use an SFH5110-33 (33 kHz) or an SFH5110-40 (40 kHz) if it suits your purpose.

Here T1 simply acts as an inverter, so a signal with the right polarity for IC2 is available at R2. When IC1 receives IR light, its output goes low and the collector of T1 goes high. This signal drives the Reset input of the timer IC (IC2), which acts as a controlled 36-kHz signal source.

IC2 acts as an oscillator. As long as T1 provides a 'high' signal, a pulse waveform at the desired frequency of 36 kHz is present at the output. The frequency is determined by R3, R4 and C2. Although the frequency may vary slightly due to component tolerances, this does not have a significant effect in practice. In summary, we can say that whenever the receiver sees IR light, the circuit emits IR light at a frequency of 36 kHz via IC2 and the IR LED (D1).

Transistor T2 is an amplifier stage that provides the current through the LED (approximately 60 mA). The current pulses are filtered by R6 and C3 to reduce the peak load on the power source. As the maximum supply voltage is 5.5 V, a 7805 is a good choice for providing a regulated supply voltage from an unregulated DC voltage in the range of 8 to 12 V.
Take care that the light from the LED cannot fall on IC1, as otherwise the circuit will go into business on its own and constantly emit IR light, which makes it useless as remote control extender.
If necessary, you can use a length of cable to connect the IR transmitter LED to the circuit board. This worked quite well with the prototype for a distance of up to 3 metres with a twisted-pair cable. Even longer distances are probably possible.



# Eco-server

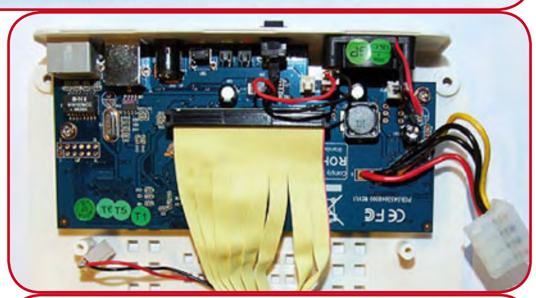


*(Dr. Thomas Scherer, Germany)*

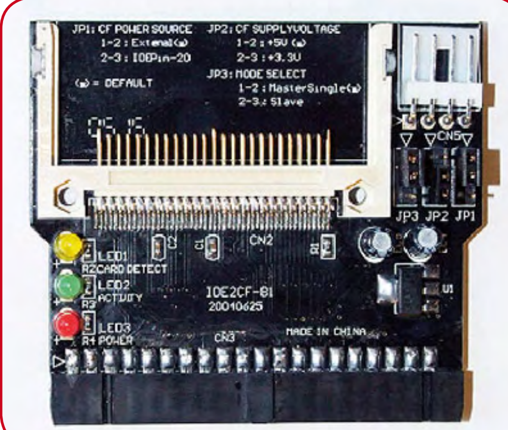
You may have considered using a server to store photos which can be shared with family and friends on the Internet or maybe you would prefer to host pictures of your eBay sale items on a home server for ultimate control. All of this can be achieved with a dedicated PC (or server) but it needs to be running 24/7 which is quite wasteful and not at all eco-friendly. On top of this, to allow access it is necessary to open ports in the PC and router firewalls and this can compromise system security. A much better solution is to build this small, neat and silent internet server which consumes just 2 W and can be bought cheaply.




The eco-server can be built into the case shown. It looks like a Mac mini but is in fact a Network Attached Storage enclosure with space for a 2.5 ″ hard drive. Googling “Landisk Mac mini” should bring up a supplier (mostly European). A USB port also allows it to be used as an external drive. The item can be found at on-line auction sites where it usually retails for less than 50 euros. You get quite a lot for your money!



In addition to the mini fan and switch there are two LEDs indicating network activity and a socket for the efficient 12 V (switched mode) mains adapter input. There are connectors for the USB 2.0 and 10/100 Mbit Ethernet LAN also on the rear of the unit. In addition to its function as a USB hard drive it also contains a complete Linux PC with integrated server software including SMB for windows using the FTP necessary for Internet communications. All Administration including set-up and security configuration are performed via the integrated web site.

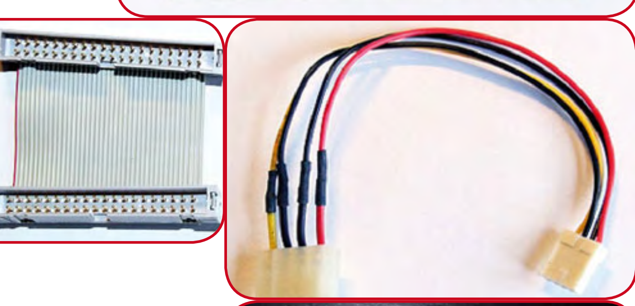



At this price you really could not build a Linux PC yourself from scratch. The power cables and IDE ribbon cable connector are shown in the photo above. The complete micro-PC uses just 150 mA at 12 V. To keep the power demands to an absolute minimum we are going completely solid-state and using a CF to IDE adaptor which allows a Compact Flash card to be fitted in place of the hard drive. Without the hard drive the fan is not required and can be disconnected. You will now need a cable to connect the CF adapter to the IDE connector; this can also be purchased for less than 10 euros.




The power connector on the adapter card is the same as that used by floppy disk drives so it is necessary to make a small adapter cable.

Unfortunately the IDE connector on some CF adapter cards is female (unlike a true hard disk which has a male connector) so it is necessary to either buy a suitable IDE extension cable or make your own gender changer using two male 40-pin connectors and a short length of ribbon cable as shown below.

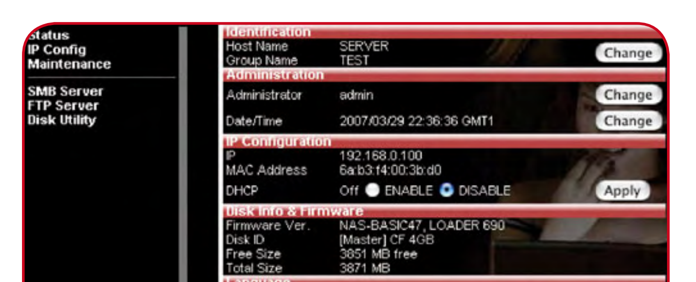


In this application the speed rating of the CF card is not critical, the 4 GB 40× card used here is fast enough and can be bought for less than 10 euros. Total power consumption for the complete mini-server is just 170 mA at 12 V = 2 W! A peek inside the case shows how it is all arranged.



The finished mini-server can just be tucked away on a convenient shelf, without a fan it runs silently. Files can be transferred to and from the card locally over SNB. Open port 21 in the router’s firewall to the server’s IP address. The server can be assigned a fixed IP address in the same address range (scope) as the router (e.g. 192.168.1.100 when the router itself has the address 192.168.1.1) and disable DHCP on the server set-up. The server has a maximum data rate of around 3.5 MB/s. Below is a screenshot of the integrated website user interface.

The eco-server is also inherently very secure; all of the software is stored in flash ROM which is relatively immune from attacks by marauding cyber vandals.

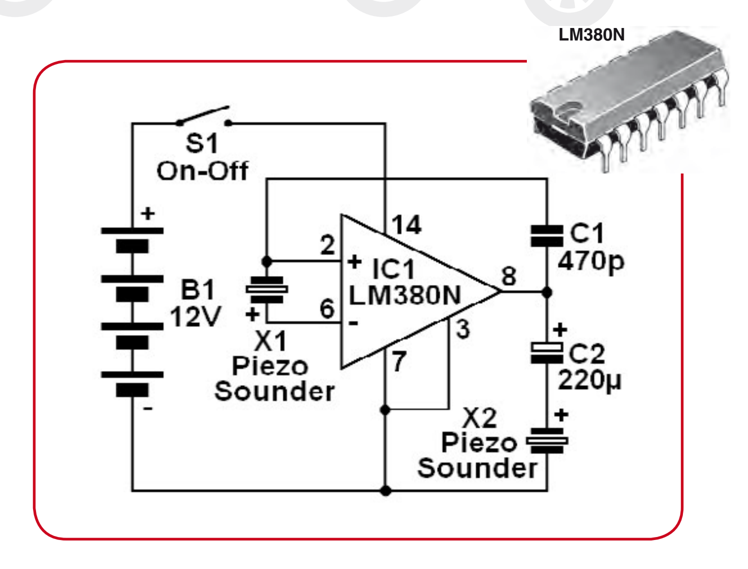


# Parking sensor (also for men...)

*Design: Thomas Scarborough (South Africa)*

Apparently there is scientific evidence suggesting that women are at a disadvantage when it comes to carrying out tasks that require a high level of spatial ability [1]. This would seem to support the cliché long held by many chauvinistic men that women will never be any good at parking their car. There are however just as many studies that refute these findings so it is not scientifically justifiable for any open-minded person to base their attitudes on the conclusions of just one study, no matter how sure they may be of its findings. Recently one of our colleagues here Pere Kersemakers the editor in charge of i-Trixx, himself a confident car driver, made a complete hash trying to park his car on the street between two other cars. He came away with more than just a dent to his pride. Needless to say, just across the road seated in front of a pub were some young women enjoying a quiet drink.
His feeble excuse at the time was that although men are normally better than women at doing some jobs they can easily get distracted... It looks like even experts might sometimes benefit from the assistance of an electronic parking sensor if only to help keep their minds focussed.

According to recent research it has been shown that a large majority of the species '*homo electronicus*' carry both X and Y chromosomes i.e. they are male. With this in mind we added the bracketed comment in the title. It was thought that otherwise the majority of readers may, after a cursory glance at the article's title, simply dismiss the article thinking that they personally could not possibly find a need for it. The truth is that many carmakers are now offering parking sensors as expensive accessories for their new models and anyway even if you do not want to use one yourself why not build one for someone you know who will find it useful?
Thomas Scarborough from South Africa has developed this very simple but useful active SONAR circuit. Using just five components it should only take a few hours to build the unit and fit to a vehicle. SONAR (**SO**und, **N**avigation **A**nd **R**anging) is a technique which uses sound propagation to detect obstacles, communicate or make measurements. The system is particularly effective underwater where it is used to make depth measurements, detect other vessels or locate fish shoals. Above the water ships also use the technique to detect obstacles in low visibility conditions. Historically the first complete sonar system was the result of collaborative work by scientists of several nations and after the Titanic disaster in 1912 there was a need for ships to be fitted with systems which could detect icebergs. Without SONAR the remains of the Titanic would not have been discovered in 1985.
The parking sensor described here works on the active SONAR principle. The circuit can detect obstacles within a range of around 1 m. The unit does not necessarily need to be fitted in a car bumper it can also be mounted on the end wall of a garage where it will indicate during parking when the car is close to the wall.
The operating principle is so simple that you have to wonder why it hasn't been done before. In the same way that a feedback howl occurs when a PA system is not set up correctly so that sound from the speakers bounces around the room, gets picked up by the microphone and amplified. This circuit relies on the feedback produced when a sound reflecting surface (a wall or another car) bounces the sound from X2 to X1.
The only IC used is the LM380N (IC1) power opamp which has a fixed gain of 50. The piezo sounder X2 emits the signal amplified by IC1 consisting of background noise picked up by




the sounder X1. Without a reflector the sound energy picked up by X1 is not sufficient to initiate feedback but when a reflective surface is brought closer to X1 and X2 some part of the signal will be amplified with a gain greater than unity.
The resulting feedback signal occurs at the resonant frequency of the two transducers and is in the low kilohertz band. The separation distance does not have too much influence on the resonant frequency. The tone is quite loud because peak sound pressure is achieved at resonance.
For this application it is important to use simple piezo sounders for X1/X2 and not the type which have built-in electronics to make them buzz. These are normally used to output sounds but as this circuit shows they can also be used to detect them. Make sure both transducers are the same type so that their resonant frequencies are as close as possible to get good sonar effect. C1 increases the coupling from output to input making the circuit more sensitive. C2 provides AC coupling to X2.
Using simple piezo transducers like those shown the circuit has a range of around 1 m. This can be doubled if more expensive piezo tweeters are used in place of X1 and X2.
The entire circuit can be fitted onto a small piece of perforated prototyping board. The value of 470 pF for C1 is about optimal for most applications. X1 and X2 should be mounted about 1 m apart, both facing in the same direction. Without C1 the circuit is much less sensitive so X1 and X2 can be mounted closer, with a separation of just a few centimetres. The detection range will now be from 1 to 10 cm. With one circuit mounted on the left and another on the right rear of the car you now have a useful parking aid. Try experimenting with C1 to achieve optimal range for your application.
The circuit takes around 12 mA so if the unit is fixed on the rear wall of your garage it will need a mains adapter. In constant use a set of batteries only last a few days so it would not be economically or ecologically wise to power the unit in this way.
Transducers X1 and X2 could also be positioned by a door to announce arrivals or could be used to announce 'close the door after you'. It can also serve as an alarm to protect the contents of cupboards or cabinets. With X1 and X2 fitted underneath expensive equipment like for example a laptop, it will let out an alarm beep when the equipment is lifted up.

**Internet Link**


[1] http://news.bbc.co.uk/1/hi/health/4202199.stm

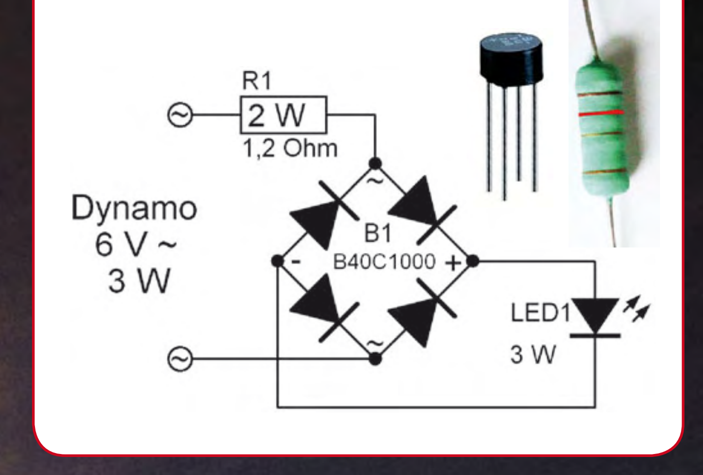
# LED bicycle lamp

Dr Thomas Scherer (Germany)

How would you feel if you had just bought a shiny new bicycle with an ‘afterglow’ rear lamp, hub dynamo, and all the mod cons, only to have the halogen bulb of the front lamp burn out after just a few kilometres? Annoyance? That’s exactly what happened to the author when he went for his first night-time ride with his new two-wheeler.
Naturally, he wasn’t keen to repeat this experience, so simply buying a new bulb (plus a spare) the next day was not a viable option. Why couldn’t the lamp be fitted with a power LED? Then he could count on 20,000 kilometres without any lamp replacement.

The author had never imagined that a little 2.4-W halogen bulb would not last even one hour on the bike. From a technical perspective, this has to do with what is called the ‘bathtub curve’: most components fail either right away or after a long time. So it was probably just bad luck – or perhaps not? Maybe the hub dynamo was the culprit. This was his first experience with such a high-tech generator on a bike. As we all know, there’s nobody faster on the draw with a screwdriver than an electronics hobbyist, so already the next morning his bicycle lamp lay in pieces on the kitchen table. He discovered that in addition to the switch, it contained a pair of 6.5-V zener diodes wired in reverse parallel to protect the bulb against excess voltage. No problem then – just bad luck.

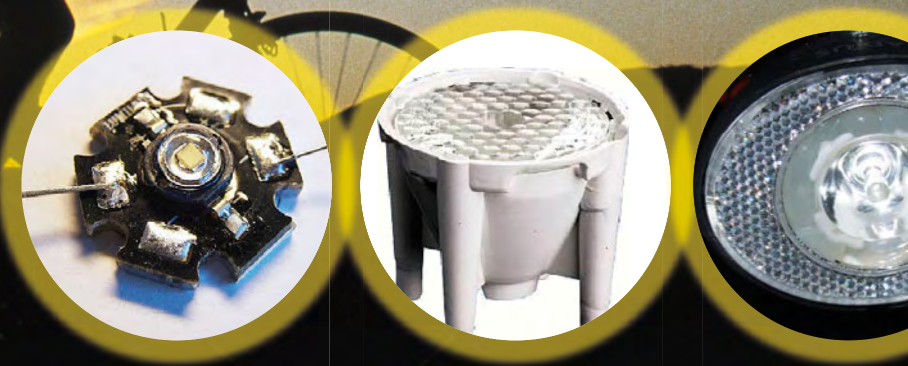
Still, he decided that from then on an incandescent lamp had no place on such a fancy bike, so it was out of the question. His resolve was firm: a LED had to go in.
Compared with a glowing coil of wire inside a glass bulb, a LED has the advantage that it not only has a longer useful life and a more constant brightness over its useful life, but also that modern LEDs actually have higher light efficiency than incandescent bulbs. The choice was thus not difficult: a LED means more light and end to bulb replacement.
Fortunately, power LEDs rated at 3 W and suitable for this application have been available for some time now. With 1-watt types, you’re more likely to end up with a hazy glow than with a real light. The next step was to order a 3-watt LED and associated optics. Optics are necessary because the radiation angle of a bare LED is too wide (more than 120 degrees), and a LED cannot use the existing lamp reflector effectively. Optics with a beam angle of 20 to 30 degrees are suitable for this purpose.



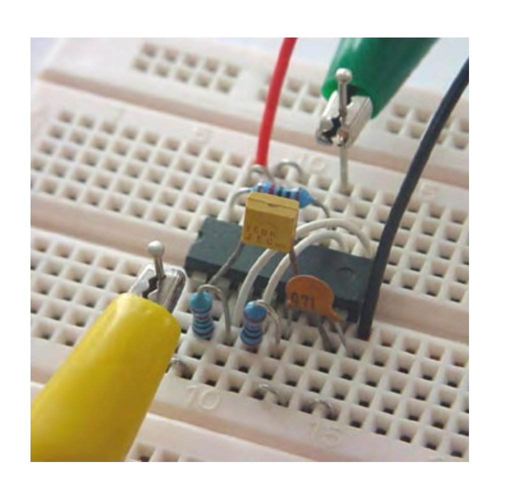

However, you need more than just a LED and the optics. A dynamo supplies roughly 6 V AC at a rated power of 3 W, which isn’t the right match. LEDs need DC, so a rectifier must be fitted upstream. The typical voltage across a Luxeon 3-W LED operating at its rated current of 700 mA is 3.7 V, which isn’t the best fit to the 6 V / 0.5 A rating of the dynamo. A bridge rectifier always has two diode junctions in series, so the voltage across the LED plus the rectifier is around 5.2 V. A 1.2-Ω / 2 W series resistor for current limiting adds another 0.84 V at a peak current of approximately 0.7 A (even a hub dynamo can’t deliver more than this). With this load, the dynamo output thus needs to be slightly more than 6 V. The LED can handle current pulses as high as 1 A.

Installation: It is usually necessary to cut a piece off the back of the reflector to make room for the LED optics. The author filled the space between the reflector and the optics with heat-melt glue. This makes a bombproof joint with the reflector. To improve heat dissipation, the small aluminium plate of the LED was bolted to a slightly larger aluminium plate with an edge length of around 4 cm. Four holes were drilled in the latter plate to receive the plastic posts at the rear of the LED optics. After the plate is fitted over the posts, the protruding ends can be pressed down with a hot soldering iron to fix the LED in place. Now you only have to find a place for the small, round bridge rectifier and resistor in the lamp housing, and you’re all set.

Postscript: Due to the imperfect match, this sort of arrangement with a 3-W LED is not much brighter than a lamp with a halogen bulb. Another issue is that the traffic regulations in some countries (guess where...) are so strict that this sort of DIY modification is simply not allowed. However, you usually won’t be ticketed for this, since a decently bright lamp is always better than a burnt-out bulb.



# Theremin Is Alive and Well



*Design: Thomas Scarborough (South Africa)*

Léon Theremin (or as he was christened, Lev Sergeivitch Termen), a Russian inventor, left the ranks of the living in 1993, but the electronic musical instrument that he invented in 1919 and which bears his name has made him nearly immortal [1]. Here we describe a modern version of this instrument, which is played without touching it and has an almost mystical aura. After an hour's worth of work with the soldering iron, you can entrance your audience with unworldly sounds.

Of course, the construction of a real theremin is more complicated than the circuit described here. By using a small medium-wave AM radio as a supplementary external component, we managed to considerably reduce the number of components. This is because a theremin is essentially nothing more than a small radio transmitter whose frequency can be modified by moving your hand closer or further away, within a range of around 30 cm. This frequency change (modulation) results from the effect of capacitive coupling, and if you select the right carrier frequency it can be converted to the audible frequency range by using a suitable receiver.

With a bit of practice, you can easily learn how to wave your hands and arms in the air close to the theremin in order to impress your listeners with melodies produced entirely under your control – a process that often appears like magic to spectators who aren't aware of how it works. The circuit described here has one distinct shortcoming relative to a genuine theremin, which is that it not possible to vary the loudness of the generated tones.

The circuit is based on a type 4093 CMOS IC. The prototype was built using a Motorola type MC14093BPC. Only three of its four gates are used here. The inputs of the unused gate (IC1d) are tied to the supply voltage rail in order to prevent interference.

The first two gates act as oscillators. Gate IC1a oscillates at approximately 3 MHz, as determined by the frequency formula $f = 1 / (2.2 \times R \times C)$. In practice, the frequency of the oscillator is slightly lower than the calculated frequency. IC1b oscillates at around 100 kHz. The outputs of the two oscillators are mixed in gate IC1c. The signal from the mixing stage is responsible for the audible tone, which can be received by a radio placed next to the circuit – not only at 3 MHz, but also at several other spots on the dial. It can even be received in the short-wave band.

With the circuit switched on, rotate the tuning knob of the radio until you find the setting where the signal has the maximum volume and the least interference. You should hear a constant tone from the speaker. If you now move your hand close to the sense electrode (marked 'Sensor' in the circuit diagram), your body capacitance acts in parallel to C1 to increase its effective capacitance. This changes the frequency of oscillator IC1a, and thus the frequency of the audible tone. With only a small amount of practice, you can learn to play the instrument and produce exactly the melody you want to hear.

Use a short, well-soldered wire to connect the sensor to the circuit board. A piece of aluminium foil or copper-plated circuit board makes a suitable sensor. In the photo, the connection is made using the yellow alligator clip.

You can use a length of coaxial cable to feed the output signal of the circuit (from the pin with the green alligator clip in the photo) to the aerial input of the AM radio used as a receiver. The screen braid of the cable must be connected to circuit ground.

As radio receivers with an aerial connector for medium-wave signals have become rather scarce nowadays, you can also fit an alligator clip to the far end of the cable and secure it to the ferrite rod antenna of the receiver.

The Theremin circuit can also be used for non-musical purposes, such as a person detector or theft alarm. If you use a large piece of aluminium foil as a sensor and place it under the doormat, the arrival of a visitor will be signalled by a change in the pitch of the tone. Naturally, you could also use a metallic door knocker as the sensor.

If an object that you want to protect against theft is placed on top of the sensor foil, it effectively becomes part of the sensor. This means that the pitch of the tone will change if the object is removed. Here the actual sensor can be concealed by a non-conductive object, such as a tablecloth, a book, or the like.

The circuit can be powered by a battery or a (non-stabilised) 12-V AC mains adapter, and it draws only a few milliamperes.

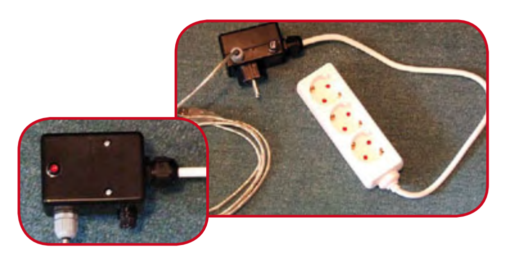
S1 On-Off
Sensor
IC1a
IC1b
IC1c
IC1d
R1 1k
R2 10k
R3 10k
B1 12V
C1 150p
C2 470p
IC1=MC14093BCP
To MW Aerial
Screen
4093

**Internet Link**
[1] www.thereminvox.com



# USB-controlled mains socket

*Dr Thomas Scherer (Germany)*

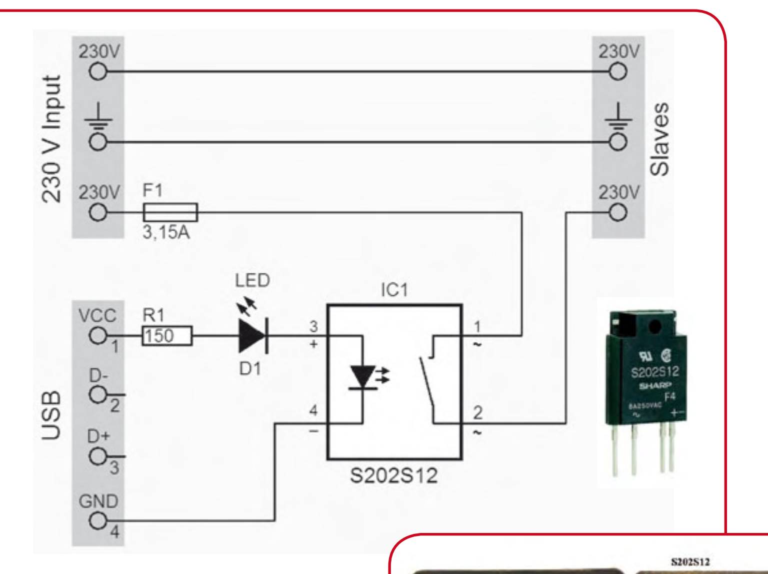


Does this sound familiar: your PC is switched off, but the monitor, speakers and so on are still consuming power because you forgot to switch off the peripheral devices? Of course, switched socket strips are available, but they aren't the most attractive desk accessories and you can't reach the switch if the strip is located under your desk. Or you may simply forget to switch it off.
A better and more convenient solution is a master/slave socket that supplies power to the 'slaves' (peripheral devices) only when the 'master' (PC) is drawing power. However, getting the sensitivity setting right is often difficult with such a device when it is used with a PC.

For a master/slave socket to work properly, it must sense the current drawn by the master and switch the power to the peripheral devices on or off when the current rises above or drops below a certain value. In addition to being convenient, this can be quite useful. For example, if power-hungry devices (such as a RAID system with a large number of disk drives and a beefy power supply) are switched on at the same time as a high-performance PC (which nowadays may feature an incredible 1-kW power supply), you run the risk of blowing a fuse or tripping an MCB. If the peripheral devices are switched as slaves, there is a time delay because the circuit takes a while to respond. This is a very nice 'side effect'.

Unfortunately, this approach does not always work reliably with a PC, because modern PCs are (unfortunately) not switched on with a proper mains switch. Instead, a button triggers a circuit that in turn enables the power stage of the power supply. Switching off the PC via 'Start' à'Turn Off Computer' is now common practice. As a result, the PC has at least three operating states with regard to power consumption: (a) normal operation, (b) various sleep states, and (c) switched off – although it still draws current in the 'off' state. The circuitry of the socket strip cannot always clearly distinguish the various states, with the result that the slave devices are sometimes switched off and on in rapid succession. In addition to being bad for the peripheral devices, this can cause premature contact wear in the relay usually fitted in the socket strip.

However, help is at hand: with only four electronic components, you can build a simple and reliable USB-controlled socket strip as shown in the schematic diagram. As you can see, all you need is a resistor, an LED (optionally red), and a solid-state relay (also called an electronic relay). IC1 can handle up to 8 A if fitted on a heat sink, which corresponds to nearly 2 kW at 230 V. As you rarely need this much power, the circuit is fitted with a 3.15-A (slow-acting) fuse F1.
Here's how it works: when the PC is on, +5 V is present on the USB ports. Consequently, a current flows through R1, LED D1 and the control input of IC1. Although a control current of 8 mA is sufficient, to be on the safe side the current is set to 13 mA here by resistor R1 (150 Ω).
Please note that this minimum-component solution is only possible with the type S202S12 relay [1]. This is because it includes not only a zero-crossing detector, but also a snubber network to reduce voltage spikes during switching.

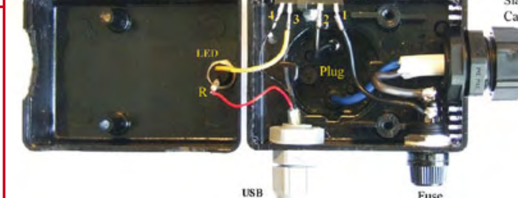



Construction: This circuit operates at **mains voltage**, which can have fatal consequences with careless or improper work. You should never simply solder the four components together and stuff them into a box, and leaving them exposed in operation is taboo – **without exception.**
Proceed as follows:

1. Obtain the four components.
2. Buy a small plastic case with a built-in mains plug.
3. Obtain a fuse holder for the fuse (panel-mount type).
4. It's also a good idea to use a bezel for the LED to hold it securely.
5. Take a USB cable, cut off the 'B' plug, strip back the cut end, and separate the individual conductors.
6. Take an AC socket strip (with three sockets) and cut off the plug.
7. It is advisable to use cable feedthroughs with compression fittings (cable glands) for the USB and mains cables (steps 5 and 6) to prevent the cables from being pulled loose. **This is important.**

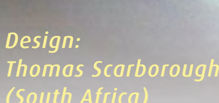
After you have prepared all of this, fit IC1 in the mains-plug case with screws and fit the LED in a (plastic) bezel. Fit the two cable glands in holes drilled for this purpose. Now pass the two cables through the glands and clamp them firmly in place. Keep the cable lengths reasonably short. Finally, use short lengths of insulated stranded wire (thin for the LED and thick for pins 1 and 2 of IC1) to wire everything together. If it looks like the accompanying photo, you can screw on the lid of the case, insert the fuse in the fuseholder, and plug the case into a mains socket.

If nothing pops (no explosion) and you don't see any smoke, use a mains tester to check the USB plug. If nothing lights up with either of the outer contacts, you can risk inserting the plug in your PC. If the red LED lights up when the PC is switched on, you have apparently done everything right and you can plug the power cables of the monitor and other peripherals into the slave sockets. With a 3.15-A fuse, you can easily handle a slave device load of up to 500 watts.



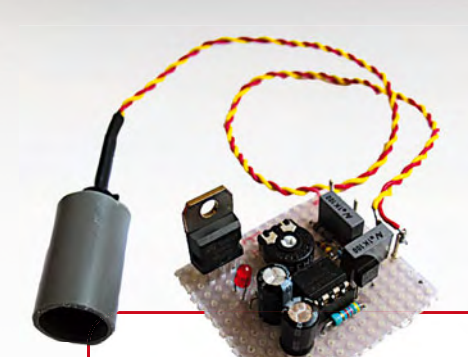

Link:[1] sharp-world.com/products/device/lineup/data/pdf/datasheet/s102s12_e.pdf

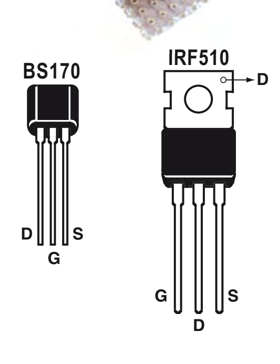
# Electronic cat's eye


*Design:*
*Thomas Scarborough*
*(South Africa)*

The eyes of almost all members of the cat family are much more sensitive at night than the human eye. At low light levels, cats not only see approximately twice as well as we do, but also notice practically every movement in their field of view – as many a small grey rodent has learned to its regret. This means that in theory a cat would make an excellent watchdog if (and there's the rub) the species *Felix catus* actually had any interest in intruders. If you use an electronic cat's eye as an intrusion detector, you can leave your feline companion to its favourite occupation (mousing).

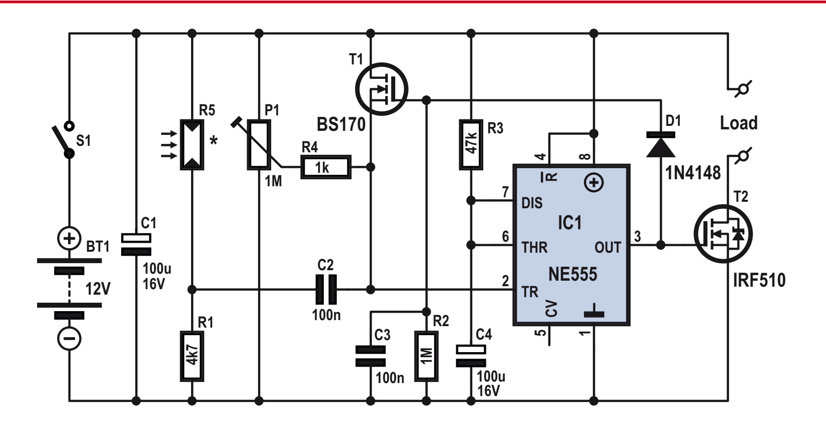
When the author decided to develop an 'electronic cat's eye', what he had had in mind was a light sensor that was as simple and sensitive as possible. His 'all-seeing eye' is a passive sensor that detects changes in brightness. This means that even this sensor is blind in full darkness, so it needs an auxiliary light source for proper operation. However, the circuit works very well in a very dim environment. As it responds to changes in brightness, the e-eye is well suited to detecting cars passing a driveway entrance or recognising cautious intruders who avoid using a pocket-lamp and work by the light of a street lamp.
If the circuit is adjusted to for maximum sensitivity, the e-eye will respond to the interruption of a light beam in the same way as a conventional light barrier and can be used to secure a range of approximately 10 m. The basic sensor element is R5, a light-dependent resistor (LDR) with type number A 9060. If you fit the LDR in a piece of blackened tube (see photo), the circuit can detect shadows on a white wall at a distance of 2 metres. The range can be increased considerably by adding a collecting lens with a focal length corresponding to the distance to the LDR.












The circuit uses the CMOS version (TLC555) of the 555 timer IC as a threshold detector.
The IC is wired as monostable multivibrator. When it is triggered by a signal on pin 2, it supplies a single positive pulse on pin 3. The pulse width is determined by R3 and C4 from
$t = 1.1 \times R3 \times C4 = 1.1 \times 47k \times 100\mu = 5.2$ s
The pulse is triggered when the voltage on pin 2 drops below one-third of the supply voltage.
Operation: The current through the illuminated LDR produces a voltage across R1. If less light falls on the LDR, the current decreases and the voltage across R1 drops. The change in the voltage across R1 is differentiated by the combination of C2, P1 and R4, with the result that only relatively fast changes in light level (and thus the voltage) reach the trigger input. The sensitivity, or in other words the amount of variation in the light level necessary to trigger a pulse, can be set with P1. The sensor thus responds to motion, as does a cat's eye, and it ignores slow changes in light level due to clouds, dawn or dusk.
Stable operation is ensured by the combination of C1, T1, R2 and C3. When the monostable is triggered, the positive output pulse drives T1 and D1 into conduction. Pin 2 is thus connected to the supply voltage to prevent detection of further light fluctuations. Due to the slow discharge of C1, IC1 remains blocked for around 0.1 second longer than the duration of the output pulse. These four components are not essential; the circuit will still work if they are omitted.
The output of IC1 switches the DMOS power FET T2, which in turn can drive a load. T2 can switch a current of up to 1 A at 12 V without a supplementary heat sink. The maximum current with a suitable heat sink is 5 A.

You can adjust the circuit for maximum sensitivity by rotating P1 until IC1 just stops being triggered automatically. R4 prevents shorting of the supply voltage via T1 when the wiper of P1 is at ground.
The quiescent current consumption is approximately 0.5 mA under dark conditions. It rises to as much as 2.5 mA under bright conditions. You can experiment with different values for C1 and R1 to see how they affect the behaviour of the circuit. To prevent triggering of the circuit immediately when it is switched on, you can connect the Reset input (pin 4) to the junction of a 1000-µF capacitor connected to ground and a 100-kΩ resistor connected to +12 V.

# Code lock

*Design: Rob Reilink (The Netherlands)*

There always seemed to be a point in old thriller movies when the camera zoomed in on beads of sweat forming on the safe cracker's face as he strains to hear through a stethoscope the sound of tumblers falling while twiddling the dial on a safe. Nowadays it's a bit more sophisticated; the scoundrel reaches into his tool bag takes out what could be a prototype breadboard that you may find lying on a bench in the Elektor labs. He attaches it to the lock mechanism, presses a few buttons, lights flash accompanied by some bleeps that you would expect such a device to make and *bingo*, the door to the bullion vault swings open. Others fictional characters use a 'sonic screwdriver' to gain entry or escape from marauding aliens.

From a safety point of view if the code lock is used for entry/exit control it is essential to provide an alternative means of escape for use in the event of a fire.The electronic level of protection is quite good but as you will appreciate the security of any code lock system is also a function of the robustness of the key pad and how firmly it is mounted.

Sturdy mechanical locks are still widely in use for security purposes but ever more electronics-based systems are appearing on the market. The most familiar electronic security system is the door entry device where a code sequence is entered using a numeric keypad. Rob Reilink's circuit suggestion shown here performs this job admirably while using very few components.

The circuit is built around the CMOS 10-stage Johnson counter type 4017. With this device only one of the ten outputs (0 to 9) is ever high. In this application it is configured to count on the falling clock edges. At reset only output 1 is high and with each falling clock edge the high is transferred to the next o/p. When it reaches 9 the next active clock edge transfers it back to 0 and the process repeats.

It is important to make sure that you have the right type of keypad for this circuit; do not use the type that are commonly used for calculators or telephones where the keys are wired as a matrix, instead you need one where all the keys have one common connection. A keypad can be made up using discrete pushbuttons wired according to the circuit diagram or it may be possible to modify the wiring of a matrix type keypad. There is practically no limit to the number of keys allowed on the keypad, in fact the more keys you have the longer it would take to find the correct code by entering every possible combination. The code sequence can be up to six numbers long or if you are not too bothered about security it can be just a single number.

The unlock code is determined by the keypad wiring. The common connection to all the keys is wired to COMM. The unlock sequence shown in the circuit diagram is 1234.The first number key in the code is wired to output 0 (pin 3) of U1. The second code number key is wired to output 1 (pin 2) of U1 etc. When all the code keys have been wired up the next output pin of U1 provides the 'OUT EN' signal. In the circuit the fifth output from U1 is used to provide the 'OUT EN' signal. All other keys are wired to ground.

Operation of the circuit begins after a reset (pressing any non-code key) output 0 of U1 will go high. Transistor Q1 will be conducting because of the forward bias at its base provided by R3 and R1. The reset input of U1 (pin 15) is held low (inactive). The voltage level at the clock input of U1 (pin 13) is around 0.6 V which is interpreted as a digital '0'. When the first key in the sequence is pressed the COMM signal will go high providing a rising clock edge on pin 13, when the key is released the falling clock edge causes the counter to advance so that now only output 1 (pin2) is high. This process is repeated for the entire code sequence. When the last key is released the 'OUT EN' will go high indicating a correct code sequence and switches transistor Q2 into conduction which pulls the OUT signal low. A relay or similar electrical device can be connected between OUT and $V_{CC}$ the maximum current supplied here is approximately 100 mA.

Any incorrect key pressed will put a low on the COMM line and turn off Q1, generating a reset of the whole chip. The code sequence must now be entered from the beginning again.
It is possible to make your own PCB using the layout shown here (see the Elektor website for more information on this design) when the images have been transferred to transparent film check that the overall dimensions of the track side measure 40.6 x 29.2 mm.
The circuit can be powered with a voltage in the range of 3 to 15 V. The circuit takes a quiescent current of around 30 µA at 3 V. Two standard AA batteries should be capable of powering the circuit for over a year. When the batteries go flat or the mains power fails (when powered by a mains adapter) the code lock will remain locked.

# Capricious blinking light

*Design: Thomas Scarborough (South Africa)*

One of the many good features of electronic circuits is their reliability. When you switch on your television set, you expect to see a picture appear on the screen a short time later. If the screen remains dark, you can rightfully assume that there's something wrong somewhere. This predictability even extends to the behaviour of DIY circuits and their components, as can be seen from the explosion and cloud of smoke that usually occur if you accidentally connect an electrolytic capacitor the wrong way round. To put it briefly, we could say that it's almost impossible to build a circuit whose behaviour cannot be predicted – but is this really true?

To give an example, you can quickly and easily put together a circuit that uses astable multivibrators (AMVs) to drive blinking LEDs. A characteristic feature of all such circuits is that the LEDs blink at regular intervals. However, it would be much more amusing to cause a LED to blink in a purely random manner, so that its behaviour would not be predictable.

The circuit shown here uses three AMVs built around Schmitt-trigger inverters (IC1a, IC1b. and IC1c), each of which is followed by a buffer (IC1d, IC1e, and IC1f).
To understand how this works, first assume that the output of inverter 1 is presently high. In this case, capacitor C2 at its input will be charged via the resistor (R1) connected between the output and the input. After a certain length of time, the voltage on the capacitor will reach a level that causes the inverter to change state, and the output will switch to the low level. Now the capacitor will be discharged via the resistor until the inverter changes state again, after which the process will start again from the beginning. This sequence will be repeated endlessly, or at least until the battery is used up. The time interval between the state changes depends on the values of capacitor C1 and resistor R1.

You should note that this sort of oscillator design only works properly with a Schmitt trigger. Normal inverters (and normal logic gates) cannot tolerate 'undefined' input voltages in the grey zone between the high and low levels, since such voltages can have unpredictable effects on the behaviour of the IC, and in the worst case they can lead to the destruction of the IC.
By contrast, Schmitt triggers do not have an undefined input voltage range, and the voltage ranges corresponding to the high and low input levels actually overlap.

The only task of the buffers here is to decouple the three multivibrators from the components on the right-hand side of the schematic drawing. As a capacitor cannot pass a DC voltage, capacitors C5–C7 are used to convert the rising edges of the buffer outputs into voltage pulses that cause the LED to blink briefly but brightly. This keeps the current consumption within bounds, since it primarily consists of the brief current pulses that flow when the LED blinks.
Diodes D2, D4 and D6 collectively implement a logic OR function. As a result of this arrangement, the LED blinks when it receives a voltage pulse via D2, D4 or D6. This randomness of the circuit also arises from this. Each oscillator operates at a different frequency, so the pattern of pulses at the junction of D2, D4 and D4 is constantly changing. As a result, the LED blinks in a random manner, as shown in the following diagram.

Of course, the behaviour of the circuit is not truly random, so it would perhaps be better to call it a 'pseudo-random blinker'. The three oscillators always operate at the same frequencies, so the pattern of superimposed pulses from the oscillators repeats periodically after a certain length of time. However, this time interval is so long that the repetition cannot be recognised by simply observing the blinking LED.
True random-number generators take advantage of unpredictable phenomena such as the thermal noise of resistors and semiconductors. This noise is so weak that strong amplification is necessary before it can be used. The circuitry necessary for this would be much more complex than the present circuit.

If this circuit is powered by a 9-V battery, the average current consumption (as measured over several minutes) is approximately 0.84 mA, at least with our prototypes. The peak current through the LED is 16 mA. This means that the circuit can operate for around one month from a 600-mA battery.

With a supply voltage of 12 V, the output resistance of the output transistors in the 40106 decreases, which causes the peak current through the LED to rises to approximately 28 mA. Naturally, the average current consumption of the circuit also increases accordingly.

# Moving-coil alarm sensor

*Design: Bernd Geveshausen (Germany)*

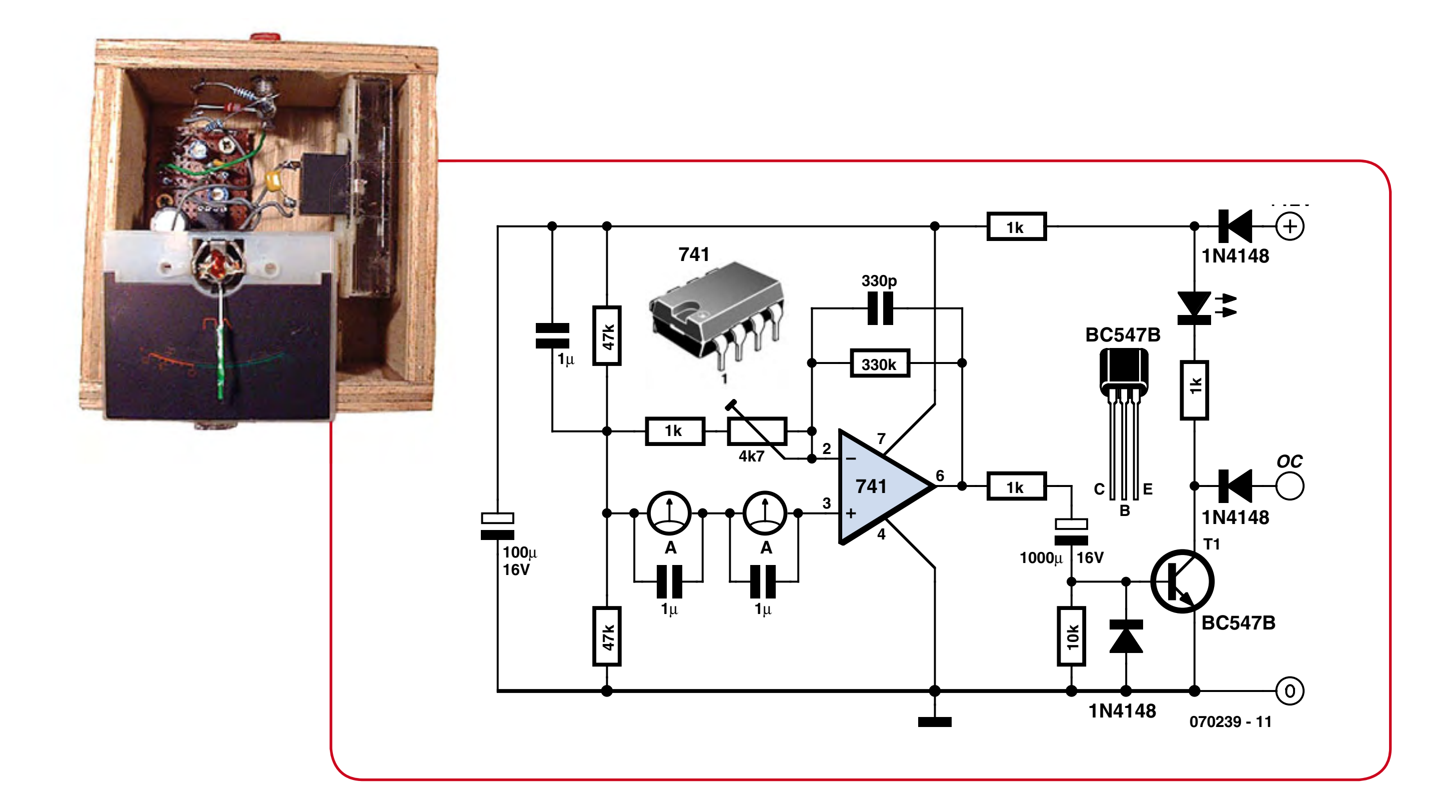
Moving coil meters belong to an era before the digital voltmeter (DVM) was invented. In those days all measurements were represented by a needle swinging back and forth in front of a graduated scale. Its name is descriptive; the meter consists of a coil (attached to the needle) pivoting in a magnetic field. The current to be measured passes through the coil and causes it (and the needle) to twist in the field.

A little while ago the Elektor offices received this circuit idea from one of our readers. Mr Bernd Geveshausen came up with an amazingly simple and unconventional alarm idea to protect his motorcycle from theft. He offered the circuit for publication and sent this photo of his finished prototype:

The circuit suggestion certainly generated some interest in the Elektor lab where we were able to dig out a few moving coil meters to test the principle. Mr Geveshausen had the idea that a moving coil meter could also be used in reverse. Many electrical transducers have properties that are reversible. In this case if the coil is physically made to turn in the magnetic field it should be possible to measure the small current induced in the coil by this movement.
Mr Geveshausen explained his idea: “Mount the meter upside down so that the pointer is hanging down and add some weight to the tip of the pointer. The measured voltage output is now proportional to the acceleration through the pendulum axis experienced by the meter.” In other words you shake the meter and it generates a voltage... sounds like an accelerometer!
Tests carried out in the Elektor labs showed that the sensor is sensitive to any movement of the vehicle. To convert the signals from the meters to an alarm signal requires very little in the way of electronics. A photo of the prototype sent in by Mr Geveshausen is reproduced here.

The result of converting it into the Elektor circuit diagram format is also printed.

The additional weight pushed onto the end of the pointer is just a short length of insulation stripped from a wire. Two meters mounted at 90° to each other are used to measure movement of the bike through two axes. The meters are wired in series; all we need now is an amplifier to boost the signal produced by them. A standard 741 type of opamp together with a few components is all that is necessary.
The 4.7 kΩ trimmer adjusts the alarm sensitivity. When the voltage at the output of the 741 gets high enough transistor T1 (e.g. BC547B) conducts, pulling the output OC low and lighting the LED which indicates that the vibration has been detected. The diode (e.g. 1N4148) at the base of T1 protects the transistor from negative transients. A diode in series with the supply protects the circuit if the supply leads are accidentally swapped during installation. A 12 V piezo buzzer can be fitted between the open-collector OC output and the positive supply. The circuit can supply 100 mA to the load.
In the same way that Mr Geveshausen made his original circuit, the complete design is small enough to be built onto a small section of perforated prototyping board. The type of moving-coil meter that can be used in this circuit is not at all critical, just make sure that any resistor wired in series with the meter is removed before the meter is used in the circuit. Old VU meters like the ones shown in the photo will be fine.
The circuit draws around 2 mA and once installed in the bike it can be in continuous operation for about a month before the battery needs to be recharged. The type 741 IC can be replaced by a TL061 to reduce the operating current; this will allow the circuit to run continuously for around six months before the battery needs charging.



# LED Night light






*Design: Dr. Thomas Scherer (Germany)*

Some types of night light are fitted with a small 1 W fluorescent tube which provide just enough illumination to stop you bumping into things when you need to visit the bathroom in the middle of the night. The unit shown here fits into a European mains outlet but similar models are also available in the UK and US. In continuous use you can expect the fluorescent tube to last for a couple of years before it packs up. Then of course it will be necessary to think about a replacement. We are gradually becoming more aware of the impact that our throw-away culture is having on the environment, much better to recycle. The dead night light is a case in point; it can be revived with a new circuit and a set of LEDs to produce an improved version of the original design which is not just ecologically sound but also runs more efficiently and will last much longer.

The enclosure shown plugs directly into a (European Continental) mains outlet and is specifically designed to ensure that all parts of the internal circuitry are completely insulated and cannot be accidentally handled. It is important to ensure that any similar enclosure used for this circuit provides adequate insulation, mains voltage is lethal! Firstly when the old night light innards are removed make sure that the fluorescent tube is correctly disposed of and not just tossed in a bin. With the new circuit and LEDs fitted you can expect the light to last over 100,000 hrs which equates to more than 10 years continuous operation! Add to this the improved efficiency and it's clear that this design will save both money and energy.

A mains transformer is normally the first essential component that you would find in any low-voltage circuit powered from the mains. The night light enclosure is however too small. Instead the circuit uses a capacitor as a sort of pre-resistor to drop the voltage. At 50 Hz the capacitor's impedance is given by:

$Z = 1 / (2\pi \times 50\ \text{Hz} \times C1)$

One advantage of this approach is that a capacitor represents a reactive load to the supply while the consumer unit measures effective power. Better still; the majority of electrical equipment connected to the national grid has an inductive load, so the nightlight will go some (tiny) way to correct the power factor.

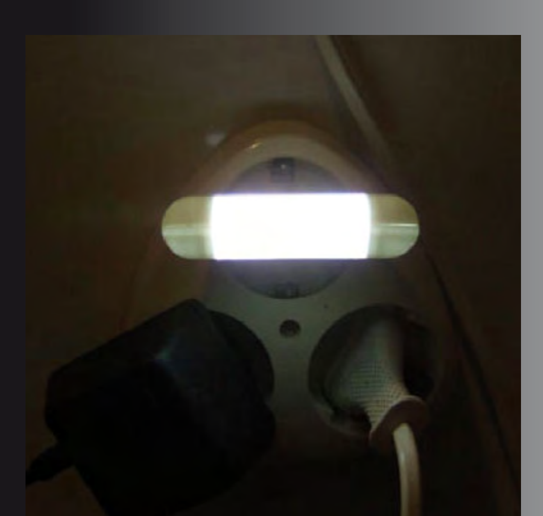
An LED is essentially a diode and only allows current to flow in one direction, connect it across a low voltage AC supply and it conducts only when it is forward biased. Two LEDs connected in anti-parallel will alternately flicker quite noticeably at 50 Hz. The circuit uses the bridge rectifier Br1 to give full wave rectification resulting in a much less noticeable 100 Hz flicker.

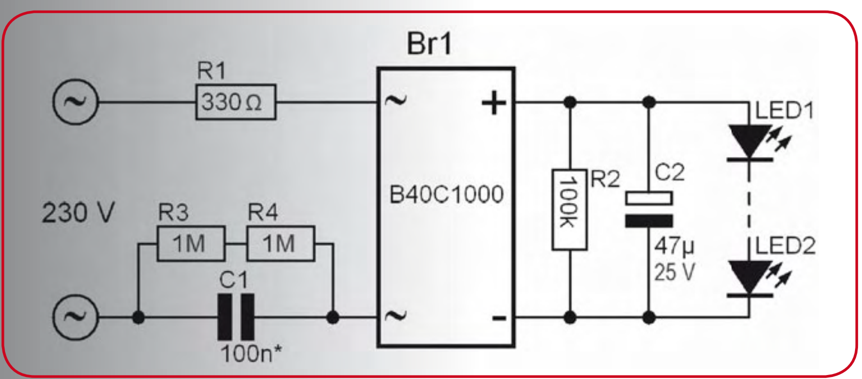
Capacitor C2 performs two functions: firstly it acts as a reservoir capacitor to smooth out the voltage peaks so that the light from the LEDs light does not flicker and secondly it protects the LEDs by absorbing any transient voltage surge which can occur when the unit is plugged in. The worst case would be if the unit is plugged in at the point that the mains voltage is at its peak value. The circuit would suddenly have 330 V across it and across C1, giving rise to a very high value of impulse current which could destroy the unit. R1 limits this surge to 1 A, at switch on C2 will be discharged and thus better able to absorb the voltage transient and protect the LEDs. R2 ensures that C2 is discharged before the unit is next plugged in.

Resistors R3 and R4 discharge any voltage remaining on C1 before it has time to give you a 'surprise' when you handle the unit after it is unplugged from the mains socket. It is important to use two resistors in series here because the voltage rating of a typical resistor is 250 V maximum. Using a single resistor here would mean that this limit is exceeded 100 times a second. It is better to use a ≥ 0.5 W carbon film resistor for R1; they tend to be more robust than metal film resistors when subjected to current surges.

Any worries concerning the lack of brightness of the new light sources were quickly laid to rest when testing the circuit. Instead of LED1 and LED2 shown in the circuit diagram the prototype was fitted with five white high-efficiency LEDs in series, each with a 10,000 mcd rating at 25 mA. The value of capacitor C1 was chosen as 330 nF to give a current of 25 mA but the result was so bright that C1 was changed to 100 nF to reduce the current to 7 mA. Fewer LEDs or less efficient types would also reduce the brightness. The overall real power drawn by the circuit was measured at only 140 mW!

One last word regarding the components; it is important to ensure that C1 is an X2 type of capacitor suitable for use at mains voltages. It should be marked with a voltage rating '250~' or higher. A DC voltage rating of 630 V (and therefore an X2 type) is also sufficient. Finally this circuit is connected to the mains, it is vital to ensure that you adhere to all safety guidelines when building and testing the circuit.





# 6-component code lock

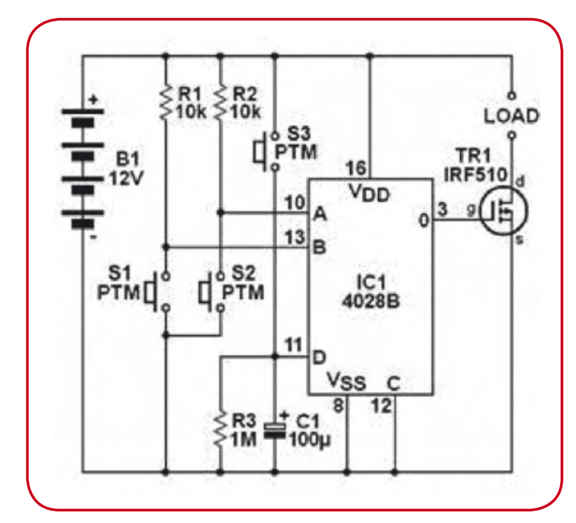
It appears that '6' is the author's favourite number. In the wake of his intercom design, he has now developed a design for a code lock that also consists of six components (if you don't count the buttons).

*Design: Thomas Scarborough (South Africa)*

A code lock circuit should be able to do more than just release an electromechanical door latch. It must also be able to reliably prevent entry by any potential intruder who doesn't know the code – which is exactly what this circuit does.
The lock releases the latch when the right pair of buttons is pressed at the same time. If any other button is pressed (here represented by button S3 in the circuit diagram), the user must wait 90 seconds before making another attempt. This makes any effort to discover the right code by trying all possible combinations a very time-consuming enterprise. For instance, you could use a 12-button keypad with all buttons except the two buttons for the desired code connected in parallel (in other words, connected as shown for S3). The fact that the right buttons must be pressed at the same time instead of in one after the other can also be regarded as a severe obstacle to unauthorised entry, since most code locks operate with sequential code entry.

The circuit is based on a type 4028B CMOS decoder IC, which is designed to convert a 4-bit binary code into a decimal value. However, this function is not used in this case. The only thing that matters here is that a '1' is present at the $0_0$ output (pin 3) when a '0' level is present on all four inputs (A–D). When this happens, power MOSFET TR1 conducts and the electromechanical latch is energised to open the door.

The C input is tied to ground ('0' level), and in the quiescent state the D input is held in the '0' state by resistor R3. In order to open the door, the user must put inputs A and B in the '0' state as well by pressing buttons S1 and S2 simultaneously.
If an incorrect button (S3) is pressed, input D is put in the '1' state, which prevents opening of the latch (a single '1' is all that is necessary for this). After this happens, capacitor C1 discharges slowly via R3 and prevents the circuit from responding to any further key presses for the next 90 seconds.
If you wish, you can increase the degree of protection against potential code breakers even further by changing the value of C1. For instance, if the value of C1 is raised to 1000 µF a potential intruder would be well advised to bring along a tent and sleeping bag ;-) . Although using a higher capacitance value may increase security, it also has drawbacks – especially if the legitimate user accidentally presses the wrong button.




As already mentioned, you can use a 12-button keypad for code entry. Select two buttons of your choice for the code and wire them as shown for S1 and S2 in the schematic diagram. Now the latch will not open unless these two buttons are pressed at the same time. Connect the rest of the buttons in parallel and wire them as shown for S3 in the diagram.

Note that many keypads have one contact of each of the buttons connected in to a common terminal. This sort of connection does not present a problem for the 'wrong' (S3) buttons, since they must anyhow be connected together. However, if S1 and S2 are also connected to this common terminal, the connection to the rest of the buttons (represented by S3) must be broken, as otherwise the supply voltage will be short-circuited. In most cases, the connection can be broken by simply scraping away the appropriate tracks on the printed circuit board.

The power MOSFET can easily handle a power level up to 10 watts. For levels higher than this (up to 43 W), it must be mounted (with insulation) on a heat sink.

The choice of mains-powered or battery-powered operation depends on the specific situation. The circuit draws almost no current in the quiescent state, so battery-powered operation is certainly possible. However, the battery must be large enough to supply the high short-term current that flows when the code lock actuates the latch solenoid. Does this mean that mains-powered operation is better in case of frequent use? Perhaps, but you should also consider what happens when there is power failure.

# LED Blinker

*Design: Thomas Scarborough (South Africa)*

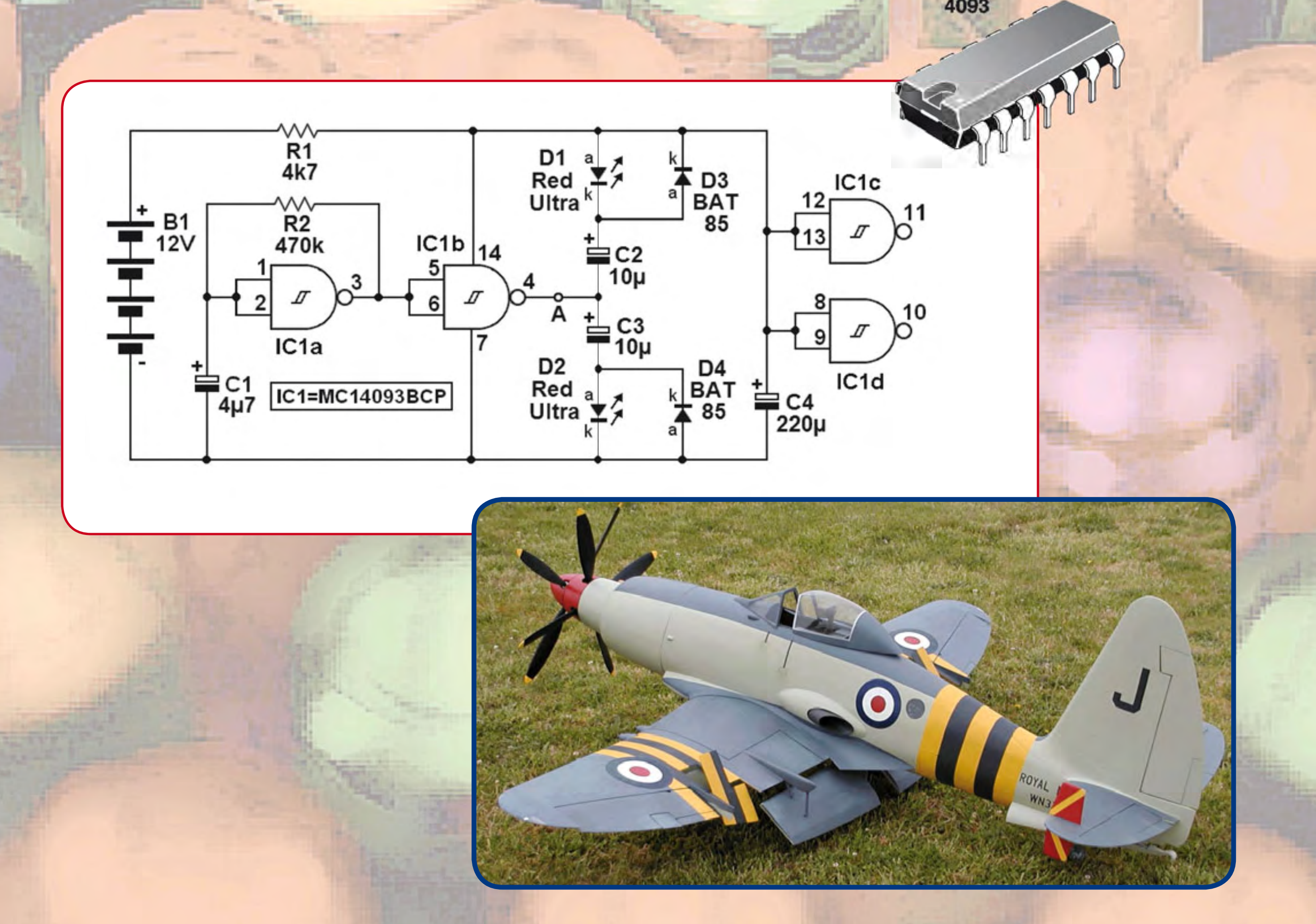
A light draws attention, and two lights draw even more attention. If they also blink or move, you can hardly miss them. This principle has long since proven its worth in the professional spheres of road and air traffic, and it can be put to good use in the private sphere of model building as well. Why shouldn't you build a model airplane with attention-getting lighting?

The simple circuit described here can cause two LEDs to blink alternately at an interval of approximately 1 second. The circuit consists of a type 4093 CMOS IC and a few peripheral components. This IC contains four NAND gates, of which only two are needed here. To avoid generating interference, the inputs of the two unused gates (IC1c and IC1d) are connected to the supply voltage line.

The operation of the circuit is quite simple. NAND gate IC1a and its associated circuitry form an oscillator. It operates at a frequency of 1 Hz and drives the second gate (IC1b), which acts as a buffer. The output of the second gate is connected to LEDs D1 and D2 via capacitors C1 and C3.
When the buffer output level changes from low to high, a charging current flows thorough C3 and causes LED D2 to light up briefly. The capacitor is charged fairly quickly because the current is only limited by the maximum output current of the gate. This results in a short current pulse, which causes the LED to emit a brief flash of light. The output level subsequently switches from high back to low, which causes C2 to charge quickly in the same manner, with the result that LED D1 flashes in the same way as D2. The net result is that the two LEDs blink alternately.

Capacitors C2 and C3 are discharged via diodes D3 and D4, respectively. These diodes also protect the LEDs against excessive reverse voltages.

The circuit can be operated from a battery with a voltage of 6 to 12 V, and it draws around 1 mA of current. If necessary, the current-limiting resistor R1 can be replaced by a wire link. In this case the current consumption will increase to 2 mA. If the blink interval is too long, the blinking rate can be increased by reducing the value of C1.
If you want to fit even more blinking LEDs in your model airplane, you can use the surplus gates (IC1c and IC1d) for this purpose. In this case, both inputs of each gate must be connected to point 'A' (the output of gate IC1b). Connect a network of the same type as the one shown connected to point 'A' in the schematic to the output of each of additional gates. R1 must be omitted in this case.





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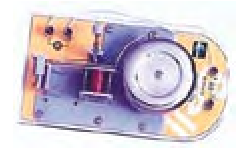

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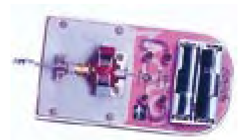

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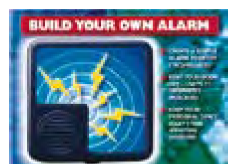
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# DOT NET on a Chip

## Microcontroller programming using C# and Microsoft Visual Studio

Jens Kühne (Germany)

**The .NET ("dot-net") Framework is a powerful tool for programming PCs as it relieves the developer of much time-consuming work. The framework is now also available, in a slimmed-down form, for 32-bit microcontrollers. It allows easy programming of I²C, SPI, Ethernet and many other functions without the need to get to grips with the details of the hardware. What's more, a development environment is available for free!**

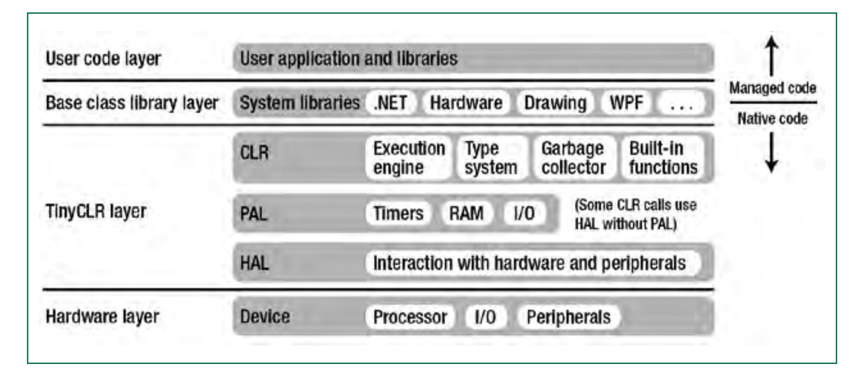



**Figure 1. Architecture of the .NET Micro Framework (HAL=Hardware Abstraction Layer, PAL=Peripheral Abstraction Layer).**

As computers become faster and faster and are equipped with more and more memory, programming becomes easier and easier. Few software developers bother with assembly code these days as most applications can be realised using higher-level programming languages. Not only does this reduce development time, it also gives the code a much greater degree of independence from the underlying hardware.

The Microsoft .NET Framework takes software development to a new level. The source code, which can be written for example in C#, an object-oriented version of C, is first translated into an intermediate language which is independent of the target hardware platform. This 'managed code' is then translated into machine language only at run-time by the so-called 'Common Language Runtime', or CLR. To this is added a wide selection of base classes which are designed to simplify almost any conceivable programming task, ranging from low-level hardware control to database interfacing and graphical output. Finally, there is an easy-to-use development environment called Visual Studio, of which the so-called 'Express Edition' is available free of charge. Early next year *Elektor* plans to publish a two-part hands-on series on programming PCs using .NET.

### Embedded .NET

A .NET framework for embedded applications has been available since 2007, following Microsoft's introduction of the .NET Compact Framework for PDAs and similar devices. The .NET Micro Framework is a small and efficient .NET run-time system that can run managed code on 32-bit microcontrollers. Anyone at home with Visual Studio and perhaps with C# will now be able to use this tool and modern programming language for programming microcontrollers. Visual Basic is not currently supported, but this situation may change in the future. Compilation of source code (i.e., its translation into managed code) works in essentially the same way as for the desktop version of the .NET framework (see text box).

The .NET Micro Framework does not require an underlying operating system. A slimmed-down version of the Common Language Runtime communicates directly with the hardware (and is therefore also known as the bootable run-time environment). The run-time environment has only modest requirements: a 32-bit processor with around 100 kByte of working memory is needed. A memory management unit (MMU) is not required.

### An alternative approach

In contrast to conventional microcontroller programming, the developer no longer needs to understand the details of the hardware. The .NET Micro Framework abstracts access

## Highlights of the .NET Micro Framework (Version 3.0)

- Modern programming language: Visual C#
- Powerful and widely-used development environment: Microsoft Visual Studio 2008
- Express Edition of the development environment is free
- Hardware can be treated in an object-oriented way (managed drivers)
- Automatic memory management using garbage collection
- Powerful base class library (part of the standard .NET library, plus extensions for embedded systems development)
- Development boards available from US$ 100, with QVGA LCD panel from US$ 300, and modules from US$ 30
- Rapid prototyping and debugging with the aid of an extensible emulator
- Live on-device debugging
- Extensive hardware support: GPIO ports, serial interfaces, SPI bus, I$^2$C bus, Ethernet with TCP and UDP sockets, WLAN, LCD panels, touchscreens, USB devices; USB host functions, CAN and PWM are indirectly supported via hardware manufacturers
- Secure network connections using Secure Sockets Layer (SSL)
- User interfaces using slimmed-down Windows Presentation Foundation classes
- File systems (for example for SD cards)

to hardware using its base class library and treats hardware components as objects.

Instead of manipulating bit masks to configure hardware peripherals, the programmer can simply set the properties of an object. This approach is termed 'managed drivers'. Furthermore, the application program need not concern itself with memory organisation. A garbage collector, a familiar concept from the PC world, tidies up memory when free space is in short supply. A further advantage of this approach is that it makes porting programs between platforms as straightforward as possible.

Although not a full operating system in itself, the Framework does provide services which would normally be provided by an operating system. **Figure 1** shows the layer architecture of the .NET Micro Framework. Although the Framework does not depend on an underlying operating system, it can however make use of an operating system if available and take advantage of its services.

The .NET Micro Framework is, however, unsuitable for real-time programming. Although it is fast, there are no guarantees of deterministic performance. The garbage collector alone can give rise to several milliseconds of timing jitter. Also, managed code is inevitably executed more slowly than native code. In the .NET Micro Framework all managed code is interpreted (in contrast to the PC .NET Framework, where a 'just-in-time' compiler translates managed code into native code prior to its first execution).

### Free IDE

The Microsoft Visual Studio 2008 development environment is required to develop code for the .NET Micro Framework. A free 'Express Edition' for C# is available [1]. The .NET Micro Framework SDK plug-in can also be downloaded free of charge, and so it is possible to begin development without paying a penny for software [2] [3].
However, for each device with an installed .NET Micro Framework a fee is payable. This will be included in the

## Listing 1: Toggling a port pin

```
using System.Threading;
using Microsoft.SPOT.Hardware;

namespace GpioOutputPortSample
{
    public class Program
    {
        public static void Main()
        {
            OutputPort outputPort = new OutputPort(Cpu.Pin.GPIO_Pin0, true);
            while (true)
            {
                Thread.Sleep(500);
                outputPort.Write(!outputPort.Read()); //toggle port
            }
        }
    }
}
```

## Listing 2: Port trigger

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace GpioInterruptPortEdgeSample
{
    public class Program
    {
        public static void Main()
        {
            InterruptPort port = new InterruptPort(Cpu.Pin.GPIO_Pin3,
                                                  false, //no contact bounce filter
                                                  Port.ResistorMode.PullDown,
                                                  Port.InterruptMode.InterruptEdgeBoth);
            port.OnInterrupt += new NativeEventHandler(port_OnInterrupt);
            Thread.Sleep(Timeout.Infinite);
        }
        private static void port_OnInterrupt(uint port, uint state, TimeSpan time)
        {
            Debug.Print("Pin=" + port + " State=" + state + " Time=" + time);
        }
    }
}
```

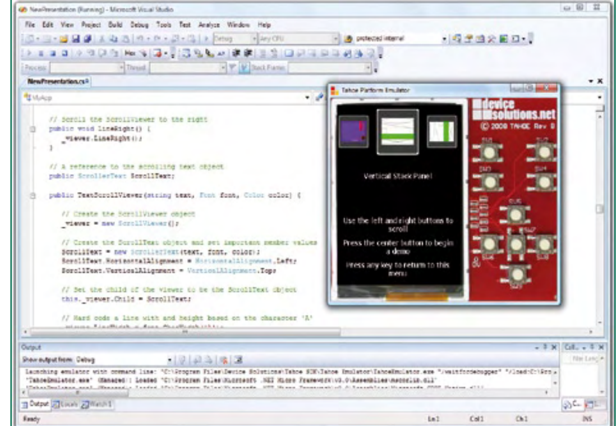


**Figure 2.**
**An emulator in action, in this case for the Tahoe development board.**

## Listing 3: Transmission over the serial port

```
using System.IO.Ports;
using System.Text;
using System.Threading;

namespace SerialPortWriteSample
{
    public class Program
    {
        public static void Main()
        {
            SerialPort serialPort = new SerialPort("COM1", 9600, Parity.None);
            byte[] outBuffer = Encoding.UTF8.GetBytes("Hello World!\r\n");
            serialPort.Write(outBuffer, 0, outBuffer.Length);
            serialPort.Dispose();
            //keeps the emulator running to see results
            Thread.Sleep(Timeout.Infinite);
        }
    }
}
```

price when a pre-configured module is used, as the manufacturer will already have paid the licence fee to Microsoft. For first experiments no hardware is required, however, as the SDK includes a extensible emulator. In essence this is a port of the CLR to the x86 processor, using an underlying operating system (Windows XP or Vista).
Direct emulation is provided of all the hardware components supported by the .NET Micro Framework (see text box). Furthermore, hardware manufacturers offer SDKs with emulators that mimic both the the appearance and the behaviour of development boards (see **Figure 2**). GPIO ports, SPI devices, I$^2$C devices, serial interfaces, LCD panels, RAMs, flash memories and many other devices can all be simulated.

More about the .NET Micro Framework can be found on the Internet [2] [3] [4] [5], and in the author's book [6].

## Platforms

Currently the .NET Micro Framework runs on ARM7- and ARM9-compatible processors. Support for Analog Devices Blackfin processors has been announced.

For application and development a number of platforms are available, which include to varying extents the range

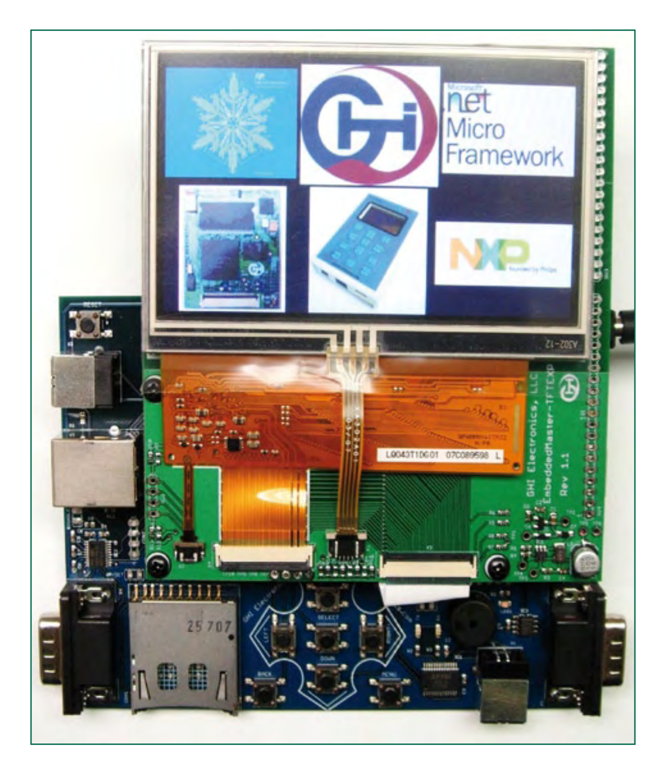



**Figure 3.**
**The Embedded Master TFT Board.**

## Compiling for the .NET Micro Framework

In .NET the compiler converts the source code into 'assemblies' (executable .EXE files and .DLL class libraries) containing code in CIL (Common Intermediate Language) and 'metadata', or self-descriptive code. The CIL code is the same, regardless of the high-level language used (C#, C++ or Visual Basic). This means that parts of a program written in C# and in Visual Basic can interoperate without problems. At run-time the managed code is executed by the CLR (Common Language Runtime) environment, which must be installed on the target processor.

The .NET Micro Framework uses a special compact version of the intermediate language to reduce ROM and RAM requirements on the target device. To this end the .NET Micro Framework metadata processor tool generates optimised 'pe-files' from the managed .NET assemblies. Visual Studio and the .NET Micro Framework plug-in hide all these steps from the user.

Currently the .NET Micro Framework only supports Visual C#. In theory any .NET language compiler could be supported, as the metadata processor reads in ordinary .NET assemblies as generated by all the .NET compilers. In practice, however, Visual Basic still uses a special Visual Basic run-time library, which has yet to be ported to the .NET Micro Framework.

of peripherals supported by the Framework. We shall look at two examples. Device Solutions [7] offers the Meridian CPU, based on a Freescale i.MXS 100 MHz ARM920T processor. It includes 8 MByte of SDRAM and 4 MByte of flash memory. The CPU module, costing US$ 75, sports an interface for a 2.7 inch QVGA LCD panel, 16 to 32 GPIO ports, two RS232 interfaces, SPI and I$^2$C interfaces and one PWM channel. The corresponding 'Tahoe' development board, which includes all the connections, a power supply and an LCD panel, is available for US$ 400.

GHI Electronics [8] offers its Embedded Master TFT Module for US$ 80 and a development board including a TFT LCD panel for US$ 350 (**Figure 3**). The company also has in its portfolio the smallest and lowest cost development system that runs the .NET Micro Framework (**Figure 4**). Priced at US$ 100, the USBizi includes a 72 MHz ARM processor, 96 kByte of RAM, 512 kByte of flash memory, an SD card slot, 44 GPIO ports (of which 35 can be configured to generate an interrupt), SPI, I$^2$C, four TTL-compatible serial ports, a 10-bit ADC and a 10-bit DAC, and much more. The LQFP100 chip from the same company

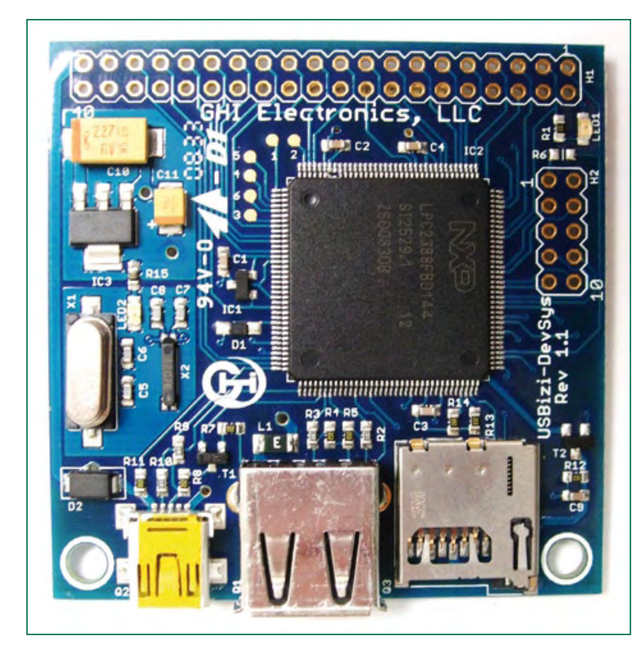



**Figure 4.**
**The USBizi development kit.**

## Listing 4: Temperature sensor on the I²C bus (managed driver)

```
using System;
using System.Threading;
using Microsoft.SPOT.Hardware;

namespace I2CTemperatureSensorSample
{
    /// <summary>
    /// Managed driver for the TMP100 temperature sensor chip
    /// from Texas Instruments on the I2C bus.
    /// </summary>
    public class TMP100Sensor
    {
        #region constants
        private const byte clockRateKHz = 59;
        private const byte REGISTER_Control = 0x01; //command to configure sensor
        private const byte REGISTER_Temperature = 0x00; //command to request result
        private const byte CONTROL_EnergyModeShutdown = 0x01;
        private const byte CONTROL_DataLengthTwelveBits = 0x60;
        private const byte CONTROL_OneShot = 0x80;
        //ms The maximum time needed by the sensor to convert 12 bits
        private const int conversionTime = 600;
        private const int transactionTimeout = 1000; //ms
        #endregion
        private readonly byte address;
        private readonly I2CDevice device;
        public TMP100Sensor(byte address)
        {
            this.address = address;
            I2CDevice.Configuration config =
            new I2CDevice.Configuration(address,
            clockRateKHz);
            this.device = new I2CDevice(config);
        }
        public float Temperature()
        {
            //write to one shot bit in control register to trigger measurement,
            //that means telling the sensor to capture the data.
            byte controlByte = CONTROL_OneShot |
            CONTROL_DataLengthTwelveBits |
            CONTROL_EnergyModeShutdown;
            byte[] captureData = new byte[] { REGISTER_Control, controlByte };
            WriteToDevice(captureData);
            //the conversion time is the maximum time
            //it takes the sensor to convert a physical reading to bits
            Thread.Sleep(conversionTime);
            //prepare the control byte to tell the sensor to send
            //the temperature register
            byte[] temperatureData = new byte[] { REGISTER_Temperature };
            WriteToDevice(temperatureData);
            //prepare the array of bytes that will hold the result
            //coming back from the sensor
            byte[] inputData = new byte[2];
            ReadFromDevice(inputData);
            //get raw temperature register
            short rawTemperature = (short)((inputData[0] << 8) | inputData[1]);
            //convert raw temperature register to Celsius degrees
            //the highest 12 Bits of the 16 Bit-Signed-Integer (short) are used
            //one digit is 0.0625 ° Celsius, divide by 16 to shift right 4 Bits
            //this results in a division by 256
            float temperature = rawTemperature * (1 / 256.0f);
            return temperature;
        }
        private void WriteToDevice(byte[] outputData)
        {
            //create an I2C write transaction to be sent to the temperature sensor
            I2CDevice.I2CTransaction writeXAction =
            device.CreateWriteTransaction(outputData);
            //the I2C data is sent here to the temperature sensor
            int transferred =
            this.device.Execute(new I2CDevice.I2CTransaction[] { writeXAction },
```

```
            transactionTimeout);
            //make sure the data was sent
            if (transferred != outputData.Length)
                throw new Exception("Could not write to device.");
        }
        private void ReadFromDevice(byte[] inputData)
        {
            //prepare a I2C read transaction to be read from the temperature sensor
            I2CDevice.I2CTransaction readXAction =
            device.CreateReadTransaction(inputData);
            //the I2C data is received here from the temperature sensor
            int transferred =
            this.device.Execute(new I2CDevice.I2CTransaction[] { readXAction },
            transactionTimeout);
            //make sure the data was received
            if (transferred != inputData.Length)
                throw new Exception("Could not read from device.");
        }
        public byte Address
        {
            get { return this.address; }
        }
    }
}
```

is a processor with similar features, measuring 20 mm by 20 mm and costing just US$ 30.

## Practical examples

**Figure 5** shows the Microsoft Visual Studio 2008 development environment with a code window and a .NET Micro Framework application. In the project properties it is possible to set where the program will be sent to for execution: choices include various installed emulators and real hardware connected over USB, network or serial interfaces.

Our listings show how simple it is to program using the .NET Micro Framework. Anyone with a basic understanding of the C programming language will find the code easy to follow. **Listing 1** shows how to use a managed driver to toggle a GPIO output pin every half second, for example to flash an LED. **Listing 2** shows how a method can be called when a GPIO input pin changes state, for example to respond to the press of a button.
It is equally straightforward to send a string of characters out over a serial port, as **Listing 3** demonstrates. Receiving data is equally easy: **Listing 4** shows a managed driver for a Texas Instruments TMP100 temperature sensor connected over the I$^2$C bus.

The GHI Electronics website [8] gives a collection of other examples (under 'Projects'), including, among other things, source code for a simple web server and Internet radio using an MP3 decoder device.

(080450-I)

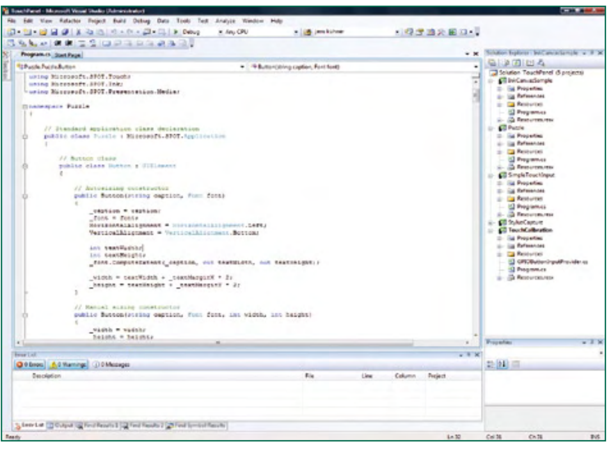


**Figure 5. The Visual Studio 2008 development environment.**


## About the author

Jens Kühner is a software developer at Vallon GmbH in Germany, working on .NET applications for the .NET Desktop and Compact Frameworks. Jens is also the author of a recently-published book 'Expert .NET Micro Framework' (Apress, 2008). He has been interested in the .NET Micro Framework from the beginning and is an active beta tester of the technology. He also writes regular articles in the .NET Micro Framework forum. He can be contacted at kuehner@web.de or via his blog [4].


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# BASCOM AVR Course

## (4) Counter and PWM

Burkhard Kainka (Germany)

**We have already taken a look at timers in part 3 of the course. The ATmega timer/counters have far more to offer than just measuring time. Here we look at impulse counting, frequency measurement and PWM signal generation.**

In the first exercise we set up timer 1 to count impulses over a period of one second. A look at the program **Listing 1** indicates that timer 1 is configured as a counter, counting on the falling edge of the input pulse and with a prescale value of 1.

The counter input is labelled T1 which for example on the Mega8 and Mega88 is pin PD5 (**Figure 1**). In this exercise we connect a low-voltage 50 Hz signal to this input via a 10 kΩ series resistor. A signal generator is not necessary here; the input impedance is relatively high so just touching the input resistor with your finger will inject a signal of sufficient level from the ambient mains field for measurement. In Europe the signal is 50 Hz, in the USA 60 Hz. The routine counts the number of pulses in 1 second so the screen shows:

```
0
50
100
150
201
251
```

After the fourth value a slight inaccuracy in the measured value creeps in. This is because the `Waitms 1000` instruction is not an exact time interval and also we have not taken into account the time necessary to output values to the display. To improve the accuracy of frequency measurements we go on in the next exercise to use timer interrupts.

### Frequency measurment

The timer can reliably count external impulses with a repetition rate of up to 4 MHz. To make accurate frequency measurements we need a precise time window, in this example we use interrupts from two timers. Each time timer 1 overflows, the interrupt is serviced by Tim1_isr which increments the variable `Highword`. Without this variable the counter would only be able to measure frequencies up to 65535 Hz (**Listing 2**).

Timer 0 generates an exact time window of one second. When the variable `Ticks = 1`, timer 1 is reset and the measurement begins. Exactly 1000 ms later the counter value of timer 1 is copied to `Lowword` and then added to the number of overflows stored in `Highword` (multiplied by 65536) before storing the result in `Freq`. The main program outputs `Freq` (in Hz) to the display every second. Initialising timer 1 in timer mode with a clock of 16 MHz (`Config Timer1 = Timer , Prescale = 1`) would display a frequency of 16000000 Hz. As a counter however, timer 1 can run at just a little more than a quarter of this frequency and its prescaler is synchronised to the processor clock. When you try to measure a frequency as high as 6 MHz for example the counter gating runs too slowly to register every edge of the input pulses so it misses some and shows a false reading of around 3 MHz. The design can be used to accurately measure frequencies up to and just beyond 4 MHz.

**Listing 1** Impulse counter

```
Test1:
Config Timer1 = Counter , Edge = Falling ,
   Prescale = 1
Start Timer1
Do
  Print Timer1
  Waitms 1000
Loop
```

### PWM outputs

Pulse Width Modulation (PWM) is a technique used in

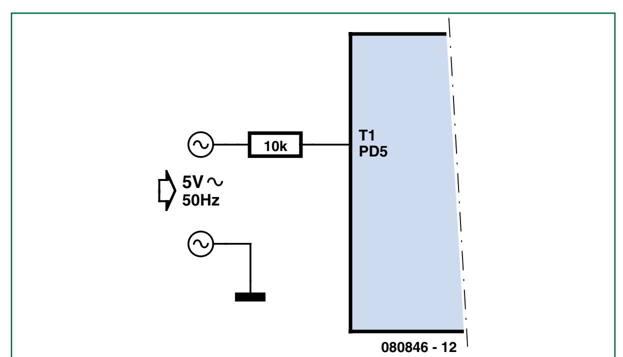



**Figure 1.** A 50 Hz signal on T1.

## Listing 2

**Frequency measurements up to 4 MHz**

```
Test2:
Dim Lowword As Word
Dim Highword As Word
Dim Ticks As Word
Dim Freq As Long
Config Adc = Single , Prescaler = 32 ,
   Reference = Off
Config Timer0 = Timer , Prescale = 64
Config Timer1 = Counter , Edge = Falling ,
   Prescale = 1
'Config Timer1 = Timer , Prescale = 1
On Ovf0 Tim0_isr
On Ovf1 Tim1_isr
Enable Timer0
Enable Timer1
Enable Interrupts

Do
  Print Freq
  Waitms 1000
Loop

Tim0_isr:
  '1000 µs
  Timer0 = 6
  Ticks = Ticks + 1
  If Ticks = 1 Then
    Timer1 = 0
    Highword = 0
  End If
  If Ticks = 1001 Then
    Lowword = Timer1
    Freq = Highword * 65536
    Freq = Freq + Lowword
    Ticks = 0
  End If
Return

Tim1_isr:
  Highword = Highword + 1
Return
```

many applications to provide a quasi-analogue control of power to a load without the need for a true D/A converter. Timers in the ATmega controllers can be used to generate

## Listing 3 **10-bit PWM**

```
Test3:
Dim Pwm As Word
Config Timer1 = Pwm , Prescale = 8 , Pwm
   = 10 , Compare A Pwm = Clear Down ,
   Compare B Pwm = Clear Down

Do
  For Pwm = 0 To 1023
    Pwm1a = Pwm
    Pwm1b = 1023 - Pwm
    Waitms 5
  Next Pwm
Loop
```

## Listing 4

**Six PWM outputs produce an LED light 'wave'.**

```
Test4:
Dim A As Single
Dim B As Single
Dim I As Byte
Dim K As Byte

Declare Sub Wave
Config Timer0 = Pwm , Prescale = 8 ,
   Compare A Pwm = Clear Down , Compare B
   Pwm = Clear Down
Config Timer1 = Pwm , Prescale = 8 , Pwm =
   8 , Compare A Pwm = Clear Down , Compare
   B Pwm = Clear Down
Config Timer2 = Pwm , Prescale = 8 ,
   Compare A Pwm = Clear Down , Compare B
   Pwm = Clear Down

Do
  For I = 1 To 60
    K = I
    Wave
    Pwm1a = Pwm
    K = I + 10
    Wave
    Pwm1b = Pwm
    K = I + 20
    Wave
    Pwm0a = Pwm
    K = I + 30
    Wave
    Pwm0b = Pwm
    K = I + 40
    Wave
    Pwm2a = Pwm
    K = I + 50
    Wave
    Pwm2b = Pwm
    Waitms 50
  Next Pwm
Loop

Sub Wave
  A = 6.1415 * K
  A = A / 60
  B = Sin(a)
  B = B + 1
  B = B * B
  B = B * 63
  Pwm = Int(b)
  If Pwm < 2 Then Pwm = 2
End Sub
```

PWM signals. Timer 1 has two independent PWM output channels with a resolution of 8, 9 or 10 bits.

**Listing 3** shows how both channels Pwm1a and Pwm1b of timer 1 can be programmed to produce output signals with 10-bit resolution. The signals are output from OC1A (PB1) and OC1B (PB2). Their electrical characteristics are the same as other port pins so you can just hang an LED together with a series current-limiting resistor on the output or connect the output to a buffer like the ULN2003 fitted to the Elektor ATM18 AVR board. The program produces increasing brightness signal from channel A and decreasing brightness signal from channel B.

## LED control using six PWM channels

The Mega88 provides six PWM outputs signals. Timers 0 and 2 both offer a resolution of eight bits. The individual outputs are on the following output pins:

OC1A on PB1
OC1B on PB2
OC0A on PD6
OC0B on PD5
OC2A on PB3
OC2B on PD3

In this last exercise we use all six PWM outputs, for the sake of symmetry in this application, timer 1 is configured with a resolution of only eight bits. The aim of this example (**Listing 4**) is to smoothly control the brightness of a row of LEDs such that a sinusoidal 'wave' of light travels along the row.

A loop with 60 brightness levels per LED is sufficient to produce a smooth transition between levels. The value of variable I is used in the sub `Wave` to produce the light level value. It is first multiplied by $2\pi$, divided by 60 and then its sine function is found. The result in the range ±1 is then offset to the range 0 to 2. The eye's perception of brightness is nonlinear so to compensate, the value is squared. It now lies in the range 0 to 4 so multiplying by 63 converts to the 0 to 255 range (almost) of PWM values used to control the LEDs.
The steps at lower values of brightness are quite noticeable so the lowest possible level is limited to 2.

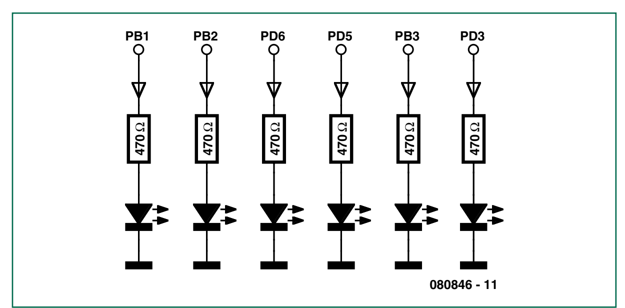



**Figure 2. Brightness control of six outputs.**

Using this calculation and the corresponding phase shift generated in the program produces an interesting lighting effect. The overall result is a wave of brightness moving along the line of LEDs. The LEDs can be arranged in a line or as a circle. It is possible to expand the line further by adding six, twelve or more LEDs.

(080846-I)

## Program downloads and forum

As usual the programming examples and additional info can be downloaded from the project page at www.elektor.com/080846. We also welcome your feedback on the Elektor forum.

# Universal User Interface

## with LCD and SD card

Michael Gaus (Germany)

**This module provides a simple user interface for extending microcontroller-based circuits. Graphics and text display commands can be sent to it over a serial interface, and, using its UART, the module reports back when the state of any of six inputs changes. Additional firmware can display a slideshow of images stored on an SD card.**

This article could equally well have been entitled 'two for the price of one': on the one hand the project described here is an update of a design published in *Elektor* in April 2007 [1]. The 'Electronic Badge' used a low-cost display from a mobile phone to display images stored on an SD card. It used an Atmel ATmega8, and we promised a future upgrade to the ATmega168. Here we make good that promise. We have also designed a printed circuit board to make the project even easier to build: the board can be ordered via our website. The ATmega168 microcontroller is a firm favourite with *Elektor* staff and readers alike, and has the benefit of allowing easy debugging using the reset input.

However, the story does not end there. In this project we can also cause the display to show vector graphics and text: using simple commands sent to the ATmega168 over a serial interface we can conjure up rectangles, lines and characters on the tiny screen. In return, the microcontroller will report (asynchronously and autonomously) over the serial interface whenever any one of six inputs changes state. This allows a keyboard, joystick or other digital input device to be connected. The whole thing thus forms a universal user interface module, which is entirely controlled, perhaps from another microcontroller, over a single serial port. This relieves the main microcontroller of dealing with user interface functions; it also avoids the need to redesign interface hardware and software for each new project.

### User interface

The universal user interface module has the advantage that the only connection required to the host microcontroller or other circuit is a single UART (TXD and RXD lines). The interface is configured to run at 115200 baud with 8 data bits, no parity and one stop bit ('8N1'), but this can easily be changed in the source code. A further advantage is its use of a particularly low-cost display. The LM15SGFNZ07 [2] [3] is used in Siemens A60, A65, C60, MC60, M55 and S55 mobile phones and is available as a spare part for well under ten pounds. The display is capable of showing graphics at a resolution of 101 by 80 pixels in 4096 colours. It takes a few simply-structured commands to the module over the UART to change foreground and background colours, show text, draw lines and rectangles and display bitmaps. This makes it easy to construct menus to control the operation of the host microcontroller or to display readings. The available commands are listed in the **text box** 'Control'.

After many of the commands a brief pause is required before the next command can be sent. As a rule of thumb, the total delay allowed should be around 10 $\mu s$ per pixel of the LCD that is updated. Commands received while the module is working will be partially or completely ignored. For this reason the user interface module sends out a one-byte status message 'command execution complete' over the serial interface when it is ready for the next command. The host should only send a new command when this status message has been received.

Reports of the status of the inputs to the module are also eight bits long. Whenever an input changes state (for example, whenever a connected pushbutton is pressed or released) a status byte is output via the UART (see text box 'Status reports'). The need for polling and debouncing of buttons is entirely avoided as a new message is automatically output on each input status change. A further feature is that if input PC0 is held low (button 1 pressed) when power is applied, the module enters a configuration menu, where it is possible, for example, to adjust the LCD contrast.

### Circuit

At the heart of the circuit (see **Figure 1**) is an ATmega168 microcontroller.
The LCD is driven over an SPI bus. The protocol was determined by author Michael Gaus by analysing the data traffic in a mobile phone (and so

# Module

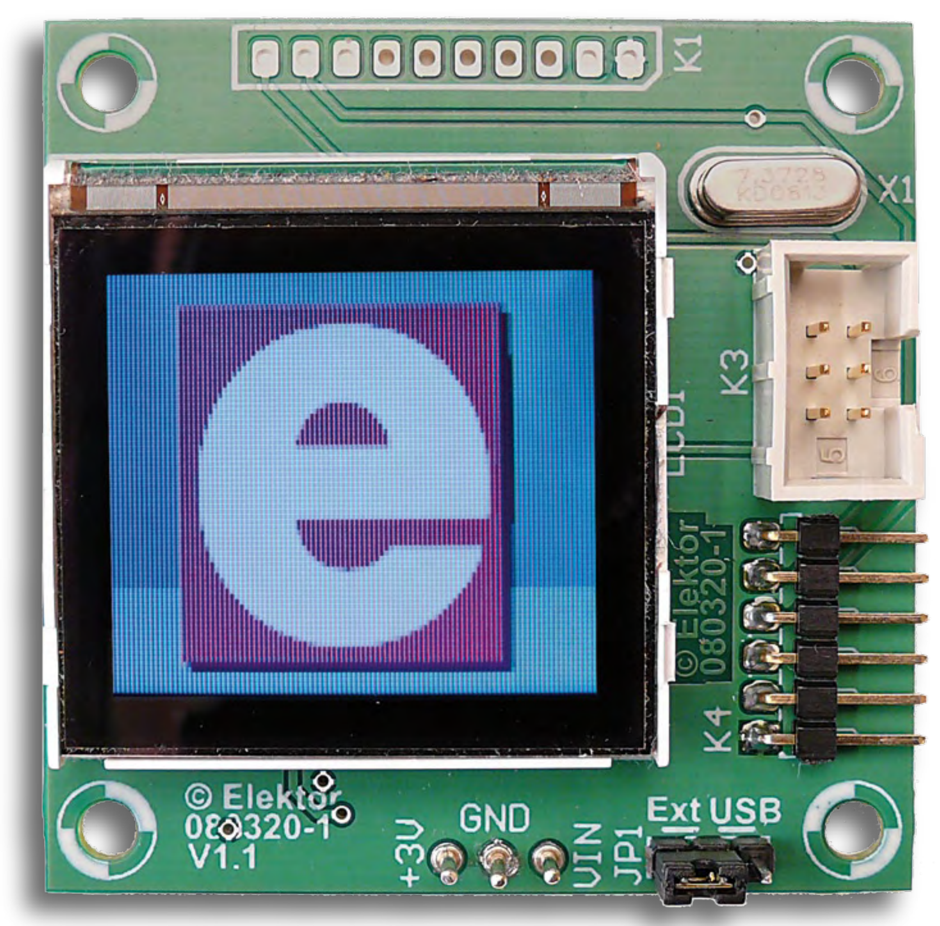



Figure 1. The popular ATmega168 lies at the heart of the circuit.

information is provided here without guarantees of correctness or completeness!). The pinout of the LCD is given in the text box 'LCD pinout'. There are solder pads on the rear of the LCD and so no special miniature connector is needed: simply solder thickish enamelled copper wire to the pads, bend the wire in a right angle and solder to the holes provided in the printed circuit board. The LCD can be further fixed to the board using a short length of double-sided adhesive tape: further advice can be found on the project website [4].

The circuit communicates with the outside world via two headers. K1 has ground connections as well as connections for the pushbuttons or other input devices. If pushbuttons are used, normally-open types are needed. K1 also carries the RXD and TXD signals of the serial interface, for example for connection to another microcontroller. The RXD (and TXD) pins of the ATmega168 are protected by internal diodes and so 5 V levels can be used: for extra safety we have added series resistor R8.

## Care and feeding

TXD and RXD are also available on pins of K4. The *Elektor* USB-to-TTL serial cable (5 V version) [5] can be connected directly to header K4. The FTDI FT232RQ device used in the cable has an input threshold voltage of typically 1.6 V, and so no level shifter is needed. The interface can of course be made fully RS-232 compatible with the addition of a MAX3232.

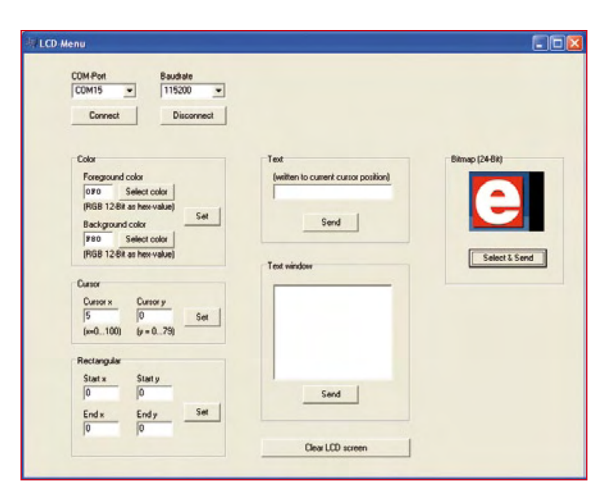



Figure 2. This PC program can be used to send a range of graphics commands to the module.

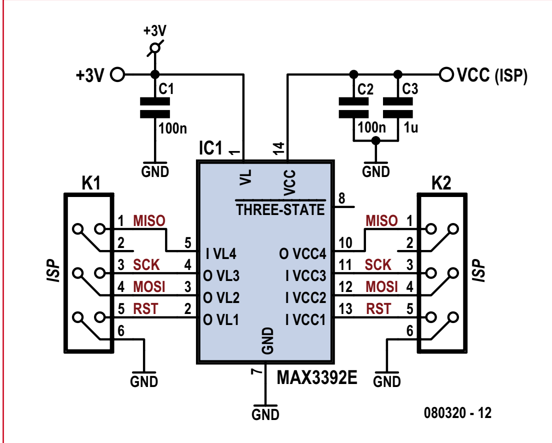



Figure 3. Suggestion for a simple programmer adaptor.

For testing and development it is convenient to connect the system to a PC running a terminal emulator program. Author Michael Gaus has written a short Windows program (see **Figure 2**) to exercise the graphics commands. This, along with the firmware for the microcontroller, is available for free download from the project pages accompanying this article [4].

If pins 2 and 3 of JP1 (marked 'USB' on the printed circuit board) are shorted together the circuit will draw its power over the USB interface. If instead three 1.5 V cells (or a regulated mains supply delivering 4 V to 5 V) are to be used, pins 1 and 2 of JP1 (marked 'Ext', for external power, on the board) should be shorted. External power can be connected either at K1 or via the pins marked 'VIN' and 'GND'.

From JP1 the supply goes to voltage regulator IC1 which produces the 3 V operating voltage for the AVR microcontroller and the LCD. In the mobile phone the LCD is operated at 2.9 V.
Diode D1 protects against reverse polarity: a Schottky type is used because of its lower forward voltage drop.
The power supply for the two LCD backlight LEDs is taken from immediately after D1, with R3 and R4 acting a current limiting resistors. D2 protects the voltage regulator in case a voltage should accidentally be applied to its output that is greater than its input voltage.

The crystal is loaded by two type NP0 ceramic capacitors, which have good temperature stability.

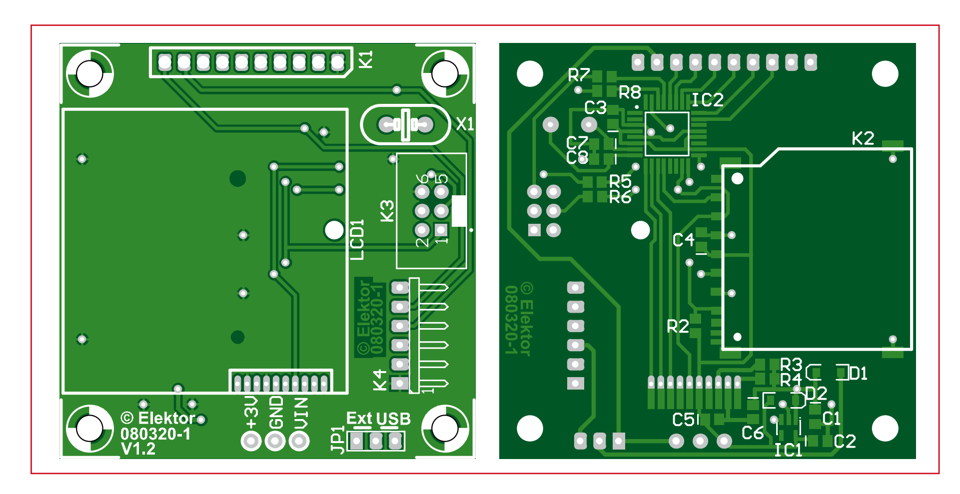
## Status reports

Whenever the state of one of the inputs changes a byte (whose bits we label D7 down to D0) is output by the microcontroller. The microcontroller also sends a status message when the processing of a command has been completed. The type of status message is encoded in the top two bits, D7 and D6. The coding structure is as follows.

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | Meaning |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | | | | | | | -reserved- |
| 0 | 1 | R | R | R | R | R | 1 | Command execution complete, ready for next command ('R' indicates reserved bits) |
| 1 | 0 | PC5 | PC4 | PC3 | PC2 | PC1 | PC0 | Sent when pushbutton input state changes. A '1' in one of the lower six bits indicates that the corresponding input is low (button pressed), while a '0' means that the input is high (button released) |
| 1 | 1 | | | | | | | -reserved- |

## Programming

An ISP-compatible programmer can be connected to connector K3. The programmer should use a voltage of between 3 V and 3.3 V to indicate a logic '1': if only 5 V levels are available, a MAX3392E (or its pin-compatible bi-directional cousin, the MAX3378E) may be used as a level shifter. **Figure 3** shows a suitable circuit, which we have not tested. The microcontroller can also be supplied with power via this circuit, pin 1 of the level shifter being connected to the terminal marked '3 V' in the main circuit. In principle this 3 V supply could also be connected via pin 2 of K3, which is not




PCB and component layout.

# COMPONENTS LIST

**Resistors**
R2 = 10kΩ, SMD 0805
R3,R4,R5,R6,R7 = 150Ω, SMD 0805
R8 = 470Ω, SMD 0805

**Capacitors**
C1,C3,C4,C5 = 100nF, SMD 0805
C2,C6 = 2µF2, SMD 0805
C7,C8 = 22pF, NP0, SMD 0805

**Semiconductors**
D1, D2 = MBR0520L, Schottky, SOD-123
(Farnell # 1467521)
IC1 = PQ1T301M2ZP, voltage regulator (LDO), 3V, 400mA, SOT-23-5 (Digikey # 425-1674-1-ND)
IC2 = ATmega168-20AU, TQFP32 (Atmel)

**Miscellaneous**
LCD1 = LM15SGFNZ07 (see text)
X1 = 7.3728MHz quartz crystal, HC-49 case
K1 = 10-way SIL pinheader, lead pitch 2.54 mm
K2 = SD card socket (Farnell # 9186158)
K3 = 6-way (2x3) boxheader, lead pitch 2.54 mm (Farnell # 1096984)
K4 = 6-way SIL pinheader, angled pins, lead pitch 2.54 mm
JP1= 3-way pinheader with jumper, lead pitch 2.54 mm
PC1,PC2,PC3 = solder pin, 1mm diameter
Enamelled copper wire, max. 0.5mm diameter
PCB, ref. 080320-1 from www.thepcbshop.com

# Control

**The user interface module is controlled over a serial port and can accept commands to draw graphics and display text. The commands available are as follows.**

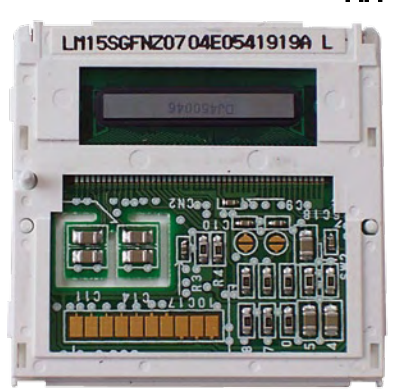
| Command (hex) | Parameter | Meaning |
|---|---|---|
| 01 | <0000rrrr> <ggggbbbb> | Set foreground colour (four bits each for red, green and blue components) |
| 02 | <0000rrrr> <ggggbbbb> | Set background colour (four bits each for red, green and blue components) |
| 03 | <x1> <y1> <x2> <y2> | Draw filled rectangle between vertices (x1,y1) and (x2,y2) |
| 04 | <x1> <y1> <x2> <y2> | Draw line from (x1,y1) to (x2,y2) |
| 05 | <x> <y> | Set text cursor position to (x,y) |
| 06 | <text> <0> | Print text (ASCII); zero byte marks end of string |
| 07 | <x1> <y1> <x2> <y2> <bitmap data> | Display bitmap image in rectangle between vertices (x1,y1) and (x2,y2): each pixel of the bitmap consists of two bytes <0000rrrr> and <ggggbbbb>, where four bits each specify the red, green and blue components |

**Notes:**
- x-coordinates must lie in the range from 0 to 100 (00 to 64 hex).
- y-coordinates must lie in the range from 0 to 79 (00 to 4F hex).
- Twelve bits in total specify a colour: four bits for each of the red, green and blue components.

**For example, to clear the screen to blue proceed by drawing a rectangle from (0,0) to (100,79) with the desired foreground colour as follows.**
- Set the foreground colour to blue (red and green components set to zero, blue component to 0F hex): 01 00 0F
- Draw a rectangle (100 in decimal is 64 hex, 79 in decimal is 4F in hex): 03 00 00 64 4F

## LCD pinout

Here are the connections to be made to the reverse of the LCD. Pin 1 is to the left, pin 10 to the right. Further information can be found on the Internet [2][3].




| Pin | Signal | Meaning |
|---|---|---|
| 1 | /CS | Chip select |
| 2 | /RESET | A reset pulse is required when power is applied |
| 3 | RS | Register select: 0 = data, 1 = command |
| 4 | CLK | Clock |
| 5 | DATA | Data |
| 6 | VCC | Approximately 3.0 V (2.9 V used in original mobile phone) |
| 7 | GND | |
| 8 | LED1_A | LED1 anode |
| 9 | LED_K | LED1 and LED2 common cathode |
| 10 | LED2_A | LED2 anode |

## Specifications

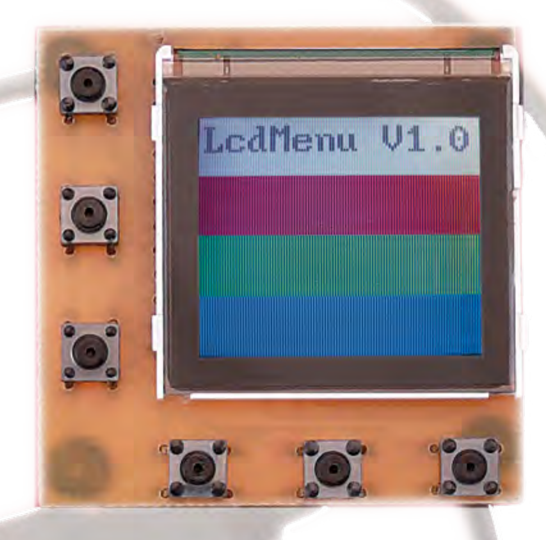
- ✔ LCD: LM15SGFNZ07 (for example from a Siemens C60 mobile phone), 101 pixels by 80 pixels, graphics, 4096 colours, LED backlight, driven over SPI connection
- ✔ LCD price: available new on eBay at low cost
- ✔ UART interface to send graphics commands and receive status messages
- ✔ Up to six inputs for pushbuttons or other digital input devices
- ✔ Supply voltage: 4 V to 5 V
- ✔ USB-to-TTL cable can be directly connected; module can be USB-powered
- ✔ SD card interface to display photographs and graphics
- ✔ LCD settings menu included in firmware

currently used, but some programmers allocate this pin as an extra power supply, and so it cannot be used safely.
The SD card socket is not used when the circuit is being employed as a user interface module. It is connected to the microcontroller in the same way as described in the 'Electronic Badge' article.

### Badge firmware

If images stored on the SD card are to be displayed on the LCD the appropriate additional firmware needs to be downloaded into the microcontroller. If PC0 is held low when power is applied (by pressing button 1) a test image appears on the display, followed by a menu. A brief press of button 1 (shorter than 500 ms) advances to the next menu entry; a long press (greater than 500 ms) selects the current entry (shown with a red background).
The corresponding action is carried out when the button is released.
The main menu allows the user to adjust the display contrast, to show an information screen, or to start a slideshow. The contrast should only need to be adjusted (if at all) within a small range of its default value of 43.
If no button is held down when power is applied a test image is displayed consisting of four coloured bars (white, red, green and blue) and the version string 'Diashow V1.1' will briefly appear. Then the bitmap images stored on the SD card are displayed in sequence with an adjustable delay between them. The delay is specified in the file config.txt stored on the SD card.
The image filenames should be at most eight characters long, followed by a dot and a three-character file extension.
The bitmaps must be exactly 101 pixels (horizontal) by 80 pixels (vertical) and the colour depth must be eight bits per channel, of which the microcontroller uses only the most significant four bits. The card must be formatted for the FAT16 file system and the files must not be fragmented. This can be achieved by writing all the images to the card in one go immediately after formatting it.
Finally, one further important piece of advice: the card must on no account be inserted or removed while power is applied to the circuit.

(080320)




## Internet links

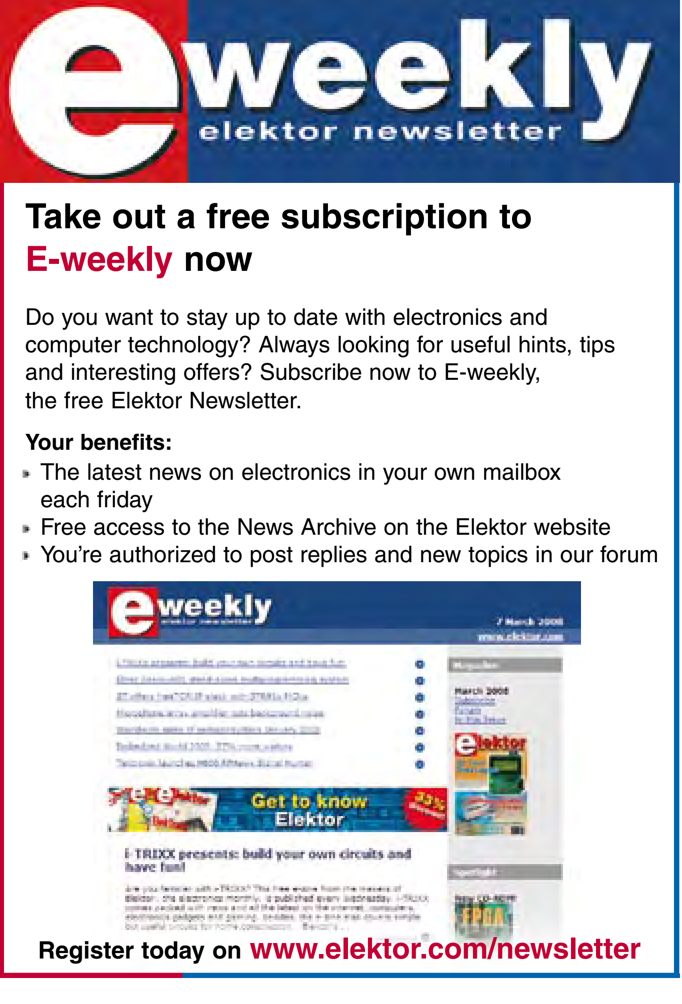

[1] http://www.elektor.fr/magazines/2007/avril/badge-electronique.81151.lynkx

[2] http://sandiding.tripod.com/m55.html

[3] http://forum.lcdinfo.com/viewtopic.php?p=8395

[4] www.elektor.fr/080320

[5] www.elektor.fr/080213



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# Electronic Transformers

## Their anatomy and application

Dr. Thomas Scherer (Germany)

**Low-voltage halogen lamps have grown in popularity since their launch in the 1980s. The same timeframe has seen the development of 'electronic transformers' that are compact, lightweight and economic. What makes them tick — and what other applications can we find for them?**

When low-voltage halogen lamps first appeared their power supplies used conventional iron-cored transformers with 12 V AC secondaries. The same applied to those trendy suspension-wire light systems using three miniature 35-W spotlights dangling from parallel wires; the insubstantial airiness of these light fittings contrasted strongly with the weighty circular core of the 100 watt transformers that fed them. Humming hefty lumps of 12 V transformer did not make installation of built-in downlighters any easier either. It's little wonder therefore that the industry was forced to develop a slimmer and less weighty substitute for the time-served transformer with its bulky iron laminations and copper windings. So please pay respect now to the electronic transformer presented in **Figure 1**.

### Anatomy

Today of course these tiny electronic transformers are all but universal. They have become so widespread and affordable that three vital questions demand an answer:

- What's actually inside these miracles of miniaturisation?
- What kind of output can we expect?
- What other applications could we dream up for these little gizmos?

No sooner said than done—and bought and dismantled. You probably guessed: inside the plastic case is nothing more than a switch-mode power supply (SMPS). Was this blindingly obvious? Not necessarily, because a close look at the printed circuit board (PCB) in **Figure 2** reveals that the electronics are less conventional than you might have guessed. Certainly we see some diodes, capacitors, an output transformer (right) and two high-voltage power MOSFETs (centre) more or less where you would expect these to be. But there are two surprises:

- For starters, the output does not appear to be provided with any rectification or electrolytics for smoothing.
- Secondly, next to the MOSFETs you might have expected a high-voltage electrolytic for filtering the rectified mains voltage.

For our first observation the obvious conclusion is that our halogen lamps must be run not on DC but on some kind of AC voltage! As far as the second is concerned, the input side of the SMPS must be supplied with a pulsating (rather than smoothed) DC voltage. Consequently we can expect the output waveform to resemble the 100 Hz output of a full-wave bridge rectifier, only the more so because the solitary 68 nF foil capacitor on the output of the diode bridge has far too little capacity to do a proper job of smoothing.

Both dodges make sense: direct current is not essential for lamp bulbs and the absence of rectification not only improves efficiency but also save hard cash. Omitting a high-voltage electrolytic saves both cost and space on the PCB. This elegance of design is matched by the fact that not a single IC is employed. On the rear side of the PCB (**Figure 3**) we discover apart from some SMD-resistors and capacitors merely three transistors and two diodes. The PCB looks a bit flimsy, being only 1 mm thick, but in fact it is made of sturdy epoxy material and not from brittle SRBP (Paxolin, Pertinax). In place of real fuses we have two thin PCB tracks drawn in zigzag fashion. The first 'what' question has now been answered.




Figure 1. An off-the-shelf 'electronic transformer' providing 60 W of power for low-voltage halogen lamps.

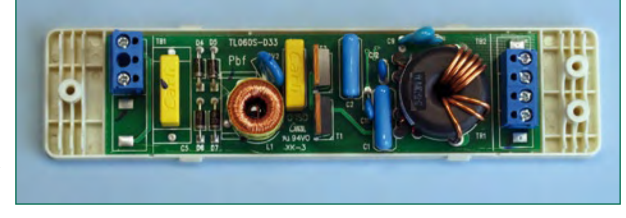


Figure 2. Inside the plastic case we find a straightforward switch-mode power supply using discrete components.

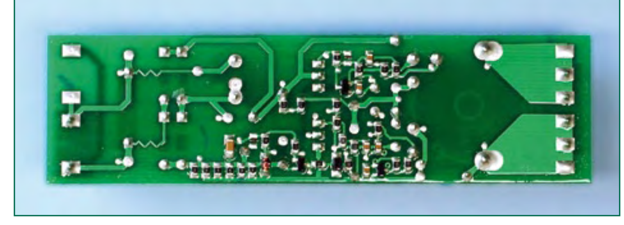


Figure 3. The rear side of the printed circuit board displays a spartan appearance, with no ICs and just a handful of semiconductors.

### Curves

The array of components used indicates that AC must appear at the output. And it's a foregone conclusion that the signal there will be in the upper kHz region. Naturally.

# Revealed and Explained

So you will be just as astonished as I was when I applied the 'scope to the output terminals. **Figure 4** shows a rather familiar waveform: it's the standard kind of 100 Hz ripple waveform you would naturally expect to see on the far side of a bridge rectifier. But not quite normal, because this waveform displays a mirror image either side of the horizontal.

The riddle is resolved in **Figure 5**: by speeding up the timebase we discover a squarewave signal of about 32 kHz at the output, which is very much what we might expect as the unrectified output of a switch-mode power supply. And as our SMPS is designed to provide a pulsating DC voltage rather than something smoothed and filtered, the output is overlaid with the 100 Hz waveform of the input. The signal of **Figure 4** consists therefore of a 32 kHz squarewave AC voltage amplitude-modulated at 100 Hz.

So, on now to our second 'what' question. Should we be concerned about the overtone frequencies of the 32 kHz squarewave signal, if it is fed to a couple of halogen lamps along two catenary (suspension) wires a metre long? Definitely, because this device would transmit a broad band of radio interference starting in the RF region and extending into medium wave territory. Disappointingly, there's no mention whatsoever of this either on the plastic case or in the instruction leaflet. Despite the pretty CE symbol displayed on the casing (and a number of international technical approval markings), a radiating electronic transformer of this kind should be better screened and ideally not used at all for catenary wire lighting.

## Applications

Now just the final 'what' question remains. Having determined that an electronic transformer is best used only with screened (metal-cased) lamp fittings, we need to say something about the stability of the output voltage. The nominal voltage of 11.2 V (unloaded) drops to 11.0 V when supplying a 5 A load current. That's certainly a fraction less than the 11.5 V marked on the unit but of adequate stability for this voltage.

Because this kind of '12 V transformer' offers such good bang for our buck — models rated at 105 W (around 8.5 A) are available cheaply — it's well worth seeing if this bargain might have alternative applications. Most of these will demand direct current and we could simply rectify and smooth the output voltage. The high switching frequency means that four Schottky diodes of adequate rating would be preferable to a normal bridge rectifier. For smoothing at 30 kHz around 100 µF/A would be adequate — were it not for the 100 Hz amplitude modulation. So let's remove it altogether.

**Figure 6** shows a temporary lash-up with a foil capacitor soldered on the rear side of the PCB, raising the capacity on the input side of the bridge rectifier to a good 700 nF. You can see how effective this is by looking at the output in **Figure 7**, where we see a signal with the 100 Hz component reduced visibly. We can improve on this: up to 50 W a high-voltage electrolytic rated 100 to 220 µF/385 V will be fine. At 100 W and more we would need to raise the capacity correspondingly. As can be seen with our modified electronic transformer in **Figure 8**, such a hefty capacitor

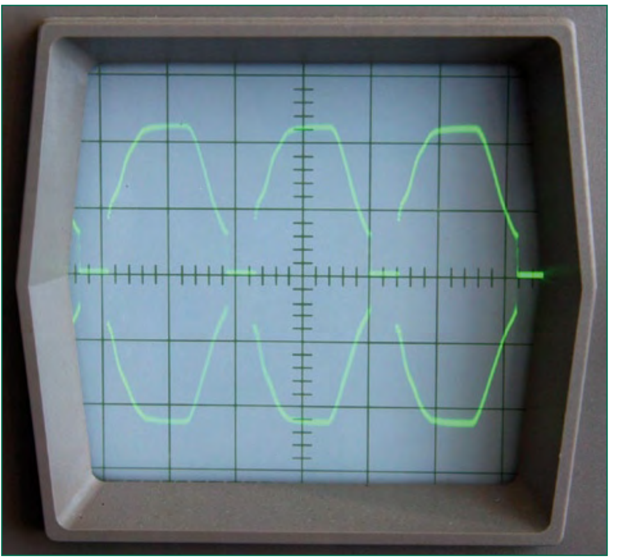


Figure 4. Output signal waveform at a timebase of 5 ms/division.

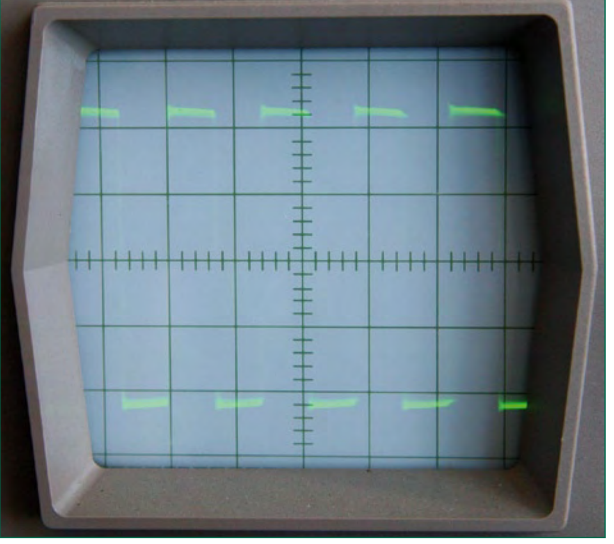


Figure 5. With the timebase reset to 20 µs/division the high-frequency component becomes visible.

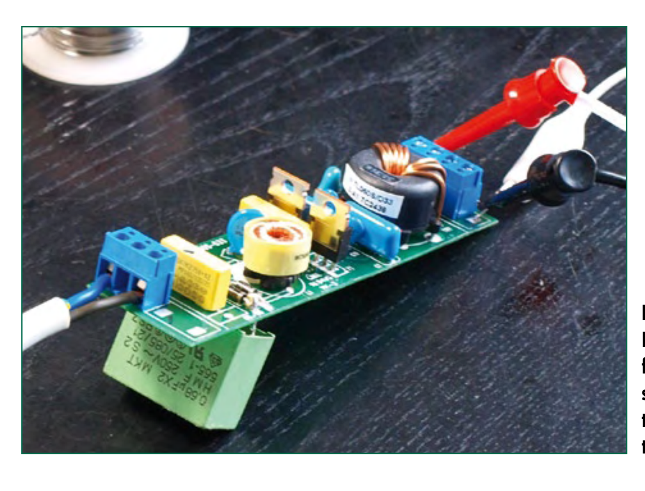


Figure 6. In this experiment a plastic foil capacitor has been soldered in cascade with the input rectifier to raise the filter capacitance value.

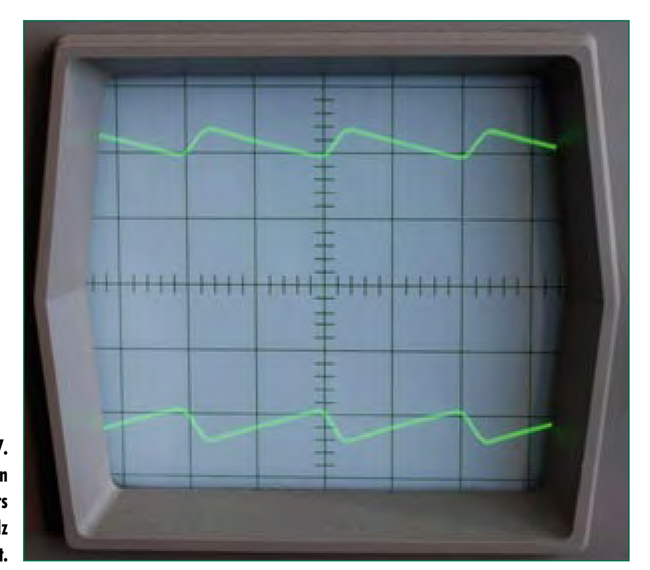
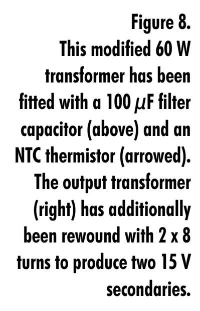


Figure 7. Improved smoothing on the input side lowers the amount of 100 Hz modulation on the output.



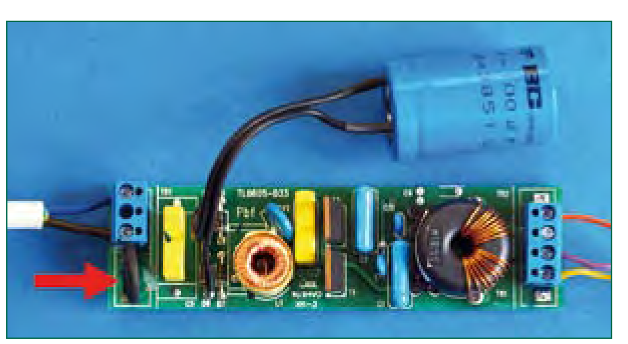


Figure 8. This modified 60 W transformer has been fitted with a 100 µF filter capacitor (above) and an NTC thermistor (arrowed). The output transformer (right) has additionally been rewound with 2 x 8 turns to produce two 15 V secondaries.

naturally will no longer fit inside the unit's plastic casing. If you are adding a high-voltage electrolytic of this kind for smoothing you will also need to fit a thermistor (NTC) with around 22 Ω cold resistance to the mains lead (arrowed in red) in order to keep the switch-on inrush within bounds.

Adequate smoothing on the output is achieved with an electrolytic rated at 1000 µF/25 V. The 25 V voltage rating is necessary because the output's peak value can rise to around 16 V. With these two modifications made, we have now created an affordable SMPS that delivers around 15 V direct current.

In **Figure 2** the eight turns of the secondary winding of the output transformer are clearly visible. As the primary winding is extremely well insulated with a layer of plastic, this enables us to remove the secondary winding and substitute something different to produce different voltages. On the models we looked at each turn produced 2 V or so. You could for example wind two enamelled copper wires in parallel and produce a winding with a precise centre tap, which would enable you to achieve full-wave rectification with just two diodes. That would save one diode path and reduce losses in the process.

Conclusion? An electronic transformer makes an ideal basis for a cheap, lightweight power supply. And 'green' too — the example illustrated develops a measured efficiency of 90 % when operating with its nominal load!

(080691-I)

## Warning!

**Any experimentation involving mains voltages demands extreme care and absolute respect for electrical safety guidelines and separation distances.**

# PLDM

# Power LED driver module

Dr. Thomas Scherer

**This year, for the first time, the efficiency of LEDs has overtaken that of fluorescent tubes. Power LEDs are thus now a realistic and energy-saving alternative to other forms of lighting. Getting them to light up, however, needs a bit of electronics, and hence the universal module described here.**

One thing is for sure: the twenty-first century will be the age of semiconductor light sources. How can we be so certain? See the text box 'LEDs today'.




Figure 1. The 3 W LED from Cree used by the author in his experiments is a particularly beautiful piece of electronics.

## Current for LEDs

Their low dynamic resistance and markedly negative temperature coefficient of forward voltage makes operating LEDs from a constant voltage source impractical. Instead, a constant current is needed. It is for the same

### Technical characteristics

- Universal switched LED current source
- Efficiency: up to 87 %
- Input voltage: 2 x 6 V AC to 2 x 27 V AC
- Maximum input voltage: 40 V
- Output current adjustable from 0.1 A to 1 A (maximum 2 A)
- Up to eight white LEDs in series
- Maximum output voltage: 34 V
- Several modules can be powered from one transformer

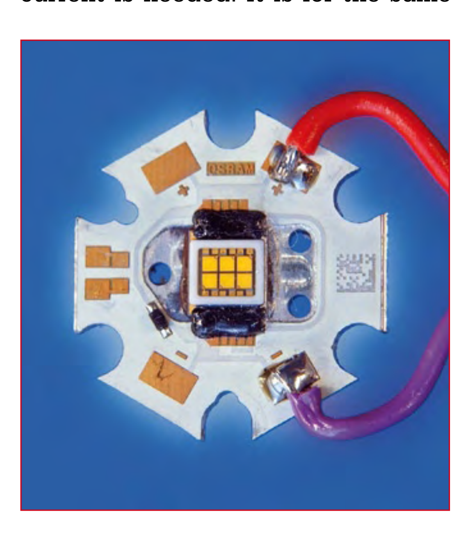



Figure 2. OSRAM's presence in the semiconductor lighting market includes OSTAR, a hex 3 W LED.

# LEDs today

**For:**

A light bulb with the standard colour temperature of 2700 K has a maximum efficiency of 15 lm/W, or 3 %.It has a life of 1000 h. A halogen lamp has four times the life expectancy, and gives out somewhat more light: a typical efficiency is 25 lm/W, or 5 %.

Fluorescent lamps can reach efficiencies of over 20 % (up to 100 lm/W) and have life expectancies of over 10000 h. Modern energy-efficient bulbs, because of their small size, only manage around 60 lm/W, and unfortunately only reach their normal brightness after a delay: at low temperatures normal brightness is never reached. They are not suitable for frequent switching.

A modern white [1] high-power LED has the following features.

- Light output efficiency of over 100 lm/W (over 150 lm/W has been achieved).
- Life of over 50000 h.
- Rapid and problem-free switching on and off.
- Small physical size opening up new opportunities for lamp design.

**Against:**

The advantages of power LEDs are so clear that it is surprising that they are not more widely available. The devices currently available that contain a large number of 5 mm LEDs are of little use. The main obstacles to adoption of LED lights are their high price and their cooling requirements.

A single good-quality white 3 W LED of the sort shown in ***Figure 1*** today costs several pounds. Special high-efficiency LEDs, 5 W types, multiple-LEDs (see ***Figure 2***) and RGB LEDs (see illustration) are considerably dearer. Also, to prolong their life, the LEDs must not be allowed to get too hot. Efficiency reduces as temperature rises, and so is also improved by adequate cooling. Good cooling is, however, difficult to provide and so it is understandable that good-quality LED lamps tend to come with a 'designer' label and a price to match.

**Warning: bright LEDs!**

**Under no circumstances look directly into the LEDs! The very bright light will not just cause discomfort, it is dangerous to the eyes as it can damage the retina.**

reasons that LEDs are normally wired in series rather than in parallel: otherwise device-to-device variations would lead to an unequal distribution of load and hence brightness.

In the case of power LEDs designed for lighting applications energy efficiency plays an important role. This means that there is no real alternative to using a switching regulator to drive the devices. Unfortunately commonly-available integrated switching regulators are designed for constant output voltage rather than constant output current. It is not easy to convert them to constant current operation because the internal reference voltage used by the error amplifier is usually in the region of 2.5 V, and is rarely less than 1.2 V. Even with a 1.2 V reference regulating the current by simply measuring the voltage drop across a shunt resistor leads to unacceptable losses: at a current of 1 A a 1.2 V voltage drop calls for a 1.2 Ω shunt resistor which will dissipate 1.2 W in wasted power. Special-purpose LED driver ICs are available, but almost invariably in hard-to-solder SMD packages. A clever little circuit offers an alternative approach.

## PLDM circuit

If we want to make use of a low-cost integrated switching regulator in a five-pin TO-220 package, such as the LM2525Z-ADJ, then the trick in converting it into a constant current source lies in artificially raising the level of the error signal. The circuit in **Figure 3**, which forms a universal driver module for power LEDs, is surprisingly simple and easy to adapt. D1 and D2 rectify the voltage from the mains transformer, which must have either two identical secondary windings or a single winding with a centre tap. In comparison to a full-wave bridge, the arrangement shown saves on the losses associated with the voltage drop across one diode. Schottky diodes keep the remaining voltage drop down to below 0.5 V. The rectified voltage supplies switching regulator IC1, a so-called 'buck' step-down converter, on pin 1. The input voltage must always be greater than the output voltage. The IC includes an error amplifier which drives a pulse-width modulator and switching transistor. The PWM signal produced appears on

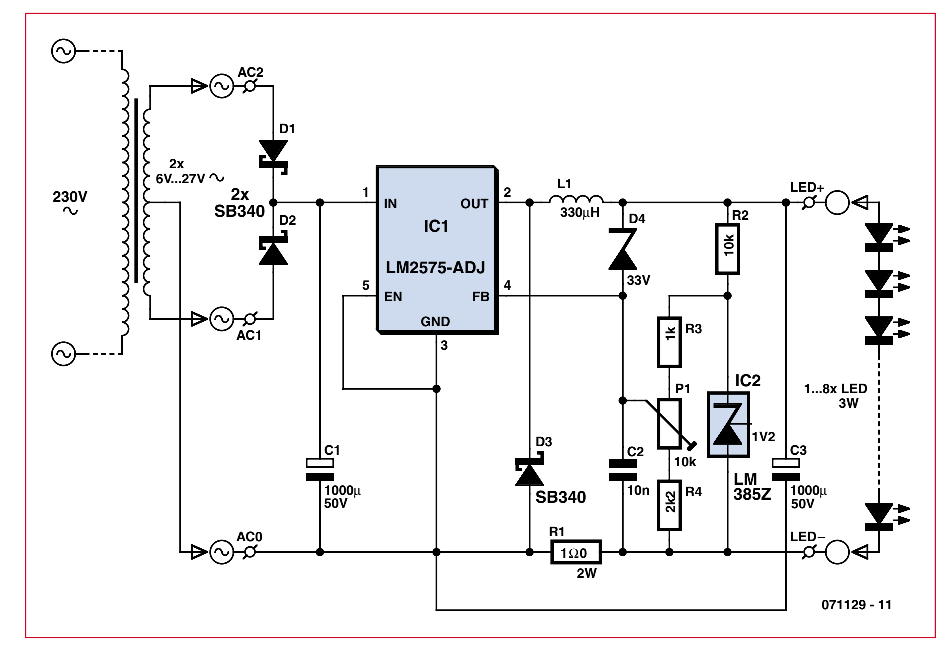



**Figure 3. Circuit of the switching voltage/current regulator.**

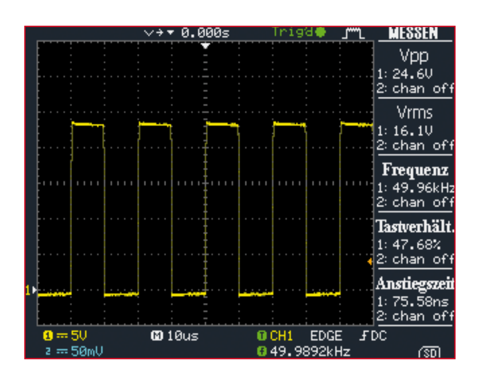



Figure 4. With a supply voltage of 25 V and five 3 W power LEDs connected to the PLDM, the mark-space ratio of the switching regulator is approximately 50 %.

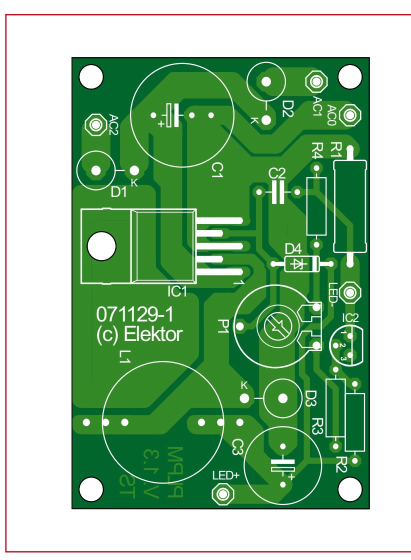



Figure 5. The PLDM printed circuit board measures just 60 mm by 40 mm.

## COMPONENTS LIST

**Resistors**
R1 = 1Ω / 2W (carbon film or metal film)
R2 = 10kΩ
R3 = 1kΩ
R4 = 2kΩ2
P1 = 10kΩ

**Capacitors**
C1 = 1000μF 50V*
C2 = 100nF
C3 = 220μF 35V*

**Semiconductors**
D1,D2,D3 = SB340*
D4 = ZPD33V*
IC1 = LM2575Z-ADJ*
IC2 = LM385Z1.2

**Miscellaneous**
L1 = 330μH / 1.9A* (SMD power inductor, e.g. FASTRON PISR-331M-04 (Reichelt # L-PISR 330μ)
Tr = 2 x 6-27 V*
PCB, ref. 071129-1

* see inset 'Power & Components'

pin 2 (see **Figure 4**). IC1 adjusts the signal so that exactly 1.2 V appears on input pin 4.
Coil L1 is a low-cost fixed inductor whose exact value is not particularly critical. It is, however, important that it is suitable for operation at around 2 A and that D3 is a Schottky diode. And here is the clever part: the voltage dropped across shunt resistor R1 is increased by 1.2V by voltage reference IC2. Using the suggested values for R3 and R4 the output current can be varied continuously between 100 mA and 1 A. Finally, D4 limits the maximum output voltage to 34.2 V.

## Construction

The text box 'Power and components' discusses tailoring the circuit to the number of LEDs to be connected. Since no SMDs are involved, there are only two points to note when populating the small printed circuit board shown in **Figure 5**.
First, diodes D1 to D3 have thick leads. Since they are mounted vertically, one of the wires has to be bent. To avoid damaging the device by excessive force on the diode's package when bending the lead it is essential to hold it firmly at the point where it enters the package using a pair of pliers.

Second, as long as the output power is less than 10 W, IC1 can be fitted flat against the printed circuit board and fixed with an M3 bolt. The M3 nut is soldered to a copper area on the reverse of the board (**Figure 6**) which will conduct the heat away. If the output power is more than 10 W a small heatsink is needed.

**Figure 7** shows the populated prototype board, fitted with a small extra piece of aluminium angle to provide adequate cooling for an output power of up to 15 W. A PLDM can drive a maximum of eight white LEDs connected in series. Several PLDMs can of course be connected in parallel across a single transformer.

## PLDM installation

If a large number of individual 1 W LEDs is used, as shown in **Figure 8**, arranging for adequate cooling is relatively straightforward. The LEDs can simply be attached to the (usually painted) sheet steel of the light fitting using a little thermal paste and nylon screws.

Things are less easy with 'proper' power LEDs rated at 3 W and above: **Figure 9** shows how the PLDM electronics can be installed along with a repurposed 'electronic transformer. In the middle is a warm white OSTAR hex LED rated at some 15 W.
Sadly, of the 15 W at least 12 W is dissipated as heat. Tests have shown that sheet steel is poor at conducting the heat away and that in operation the LED can reach blistering temperatures well in excess of 110 °C! A piece of sheet aluminium works more effectively.

(071129-I)

## Warning

**Never connect LEDs to the PLDM while power is applied to it! If C3 is charged the discharge current will almost certainly damage the LEDs. First switch off power to the PLDM, connect the LEDs, and then reapply power.**



"ACULED" from PerkinElmer Elcos

## Internet links and literature

**[1] Theory of white LEDs:**
http://en.wikipedia.org/wiki/Light-emitting_diode#White_light_LEDs

**[2] LED cooling (PerkinElmer):**
http://optoelectronics.perkinelmer.com/Content/ApplicationNotes/APP_ThermalManagementofACULEDVHL.pdf

## Power and components

Certain components in the module can be selected according to the number of LEDs connected in series to its output. The universal values, as shown in the circuit diagram, are indicated in bold.

| Number of white LEDs | | | | |
|---|---|---|---|---|
| **LEDs** | **Transformer secondary** | **C1** | **C2** | **D4** |
| 1 | 2 x 6 V | 16 V | 16 V | ZPD12V |
| 1 or 2 | 2 x 9 V | 25 V | 25 V | ZPD22V |
| 1 to 3 | 2 x 9 V | 25 V | 25 V | ZPD22V |
| 1 to 4 | 2 x 12 V | 25 V | 25 V | ZPD22V |
| 1 to 5 | 2 x 15 V | 25 V | 25 V | ZPD22V |
| 1 to 6 | 2 x 18 V | 35 V | 35 V | ZPD27V |
| 1 to 7 | 2 x 24 V | 50 V | 35 V | ZPD33V |
| **1 to 8** | **2 x 27 V** | **50 V** | **35 V** | **ZPD33V** |

The required power rating of the transformer is calculated by dividing the power required by the LEDs by the efficiency of the converter and adding a safety margin. For example, suppose we wish to connect four 3 W LEDs. The current through the LEDs is 750 mA. In the worst case the forward voltage of the LEDs is 4 V and the load is 4 x 3 = 12 W. The overall efficiency of the converter is around 85 %: using 80 % to be on the safe side, we calculate that the transformer must be capable of delivering at least 12 W / 0.8 = 15 W. An 18 VA transformer with two 12 V secondary windings is thus suitable.

It is possible to alter the circuit for higher power output (up to approximately 50 W). If R1 is replaced by a 0.47 Ω 2 W resistor, C1 by a 2200 μF capacitor, diodes D1 to D3 by type SB540, IC1 by an LM2576T-ADJ and L1 by a 100 μH inductor, it will be possible to achieve currents of up to 2 A. The P3596 is also available as a substitute for the LM2576.

When using RGB power LEDs it is important to select devices with separate anode and cathode connections for each LED. All the red LEDs can be wired in series and driven from one PLDM, the green LEDs from a second PLDM and the blue LEDs from a third PLDM. The trimmer potentiometers can then be adjusted to obtain the desired mixture of colours in the light output.

When the current through the LEDs is being adjusted using P1 it is possible to monitor the voltage drop across R1 using a voltmeter. For experimenting like this it is recommended to use a 'pseudo-LED' (consisting of a 10 Ω resistor rated at 10 W) to avoid accidentally shortening the life of the real LEDs.

## Light and temperature

It is of course a good idea to take a look at a LED's data sheet before building a LED lamp and associated driver electronics. In particular, thermal behaviour varies considerably from manufacturer to manufacturer. Graphs showing the typical spectrum of a white LED and the dependence of efficiency on temperature, and tables of typical characteristics all provide useful guidelines. Commercially-available power LEDs do not, unfortunately, yet reach laboratory-record efficiency levels of 150 lm/W. A good rule of thumb is that one LED watt is worth about four incandescent watts.

It is essential to cool power LEDs. It is simplest to use LEDs which are already mounted on a small aluminium carrier. More information on the thermal management of power LEDs can be found in [2], which is also our source for the picture of the 'ACULED'.

| Typical values for a white 3 W power LED | |
|---|---|
| Light output | 100 lm to 200 lm |
| Viewing angle (to 50 % brightness) | 120 ° |
| Life (70 % brightness) | up to 50000 h |
| Maximum junction temperature | 150 °C to 185 °C |
| Thermal resistance, junction to package | less than 15 K/W |
| Operating current | 700 mA |
| Forward voltage at 0.7 A | 3.1 V to 3.9 V |
| Temperature dependence of forward voltage | –2 mV/K |
| Dynamic resistance | less than 1 Ω |

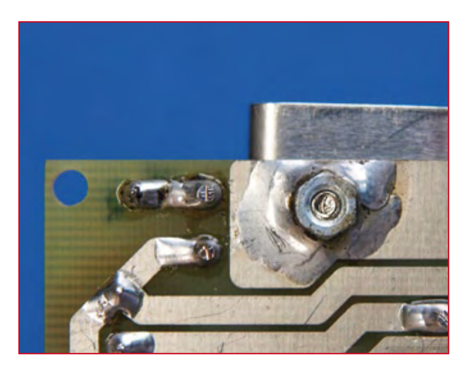


**Figure 6. For lower power applications it is sufficient to solder an M3 nut to the pad on the reverse of the printed circuit board to help dissipate heat.**

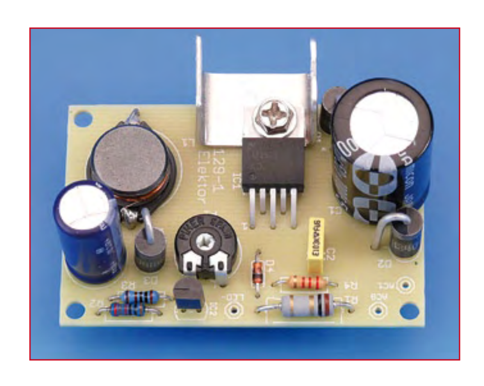


**Figure 7. The prototype: IC1 is screwed to a small piece of aluminium to provide cooling.**

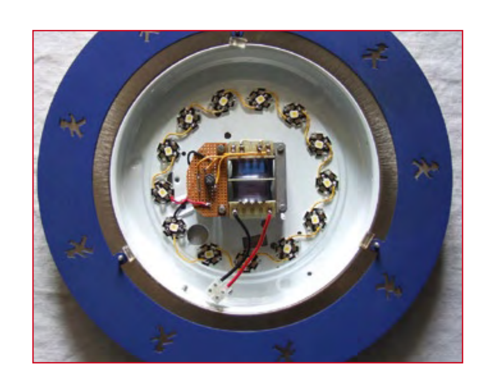


**Figure 8. An early experiment using thirteen LEDs, each rated at 1 W, in series: here without the PLDM.**

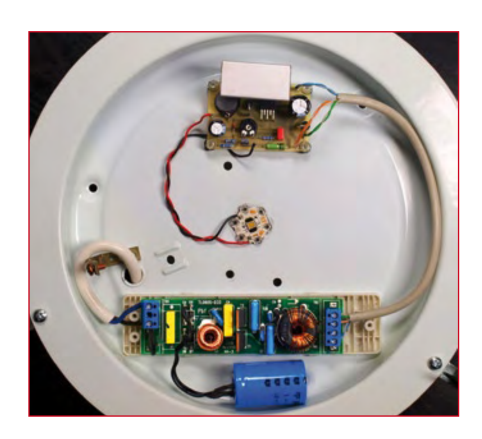
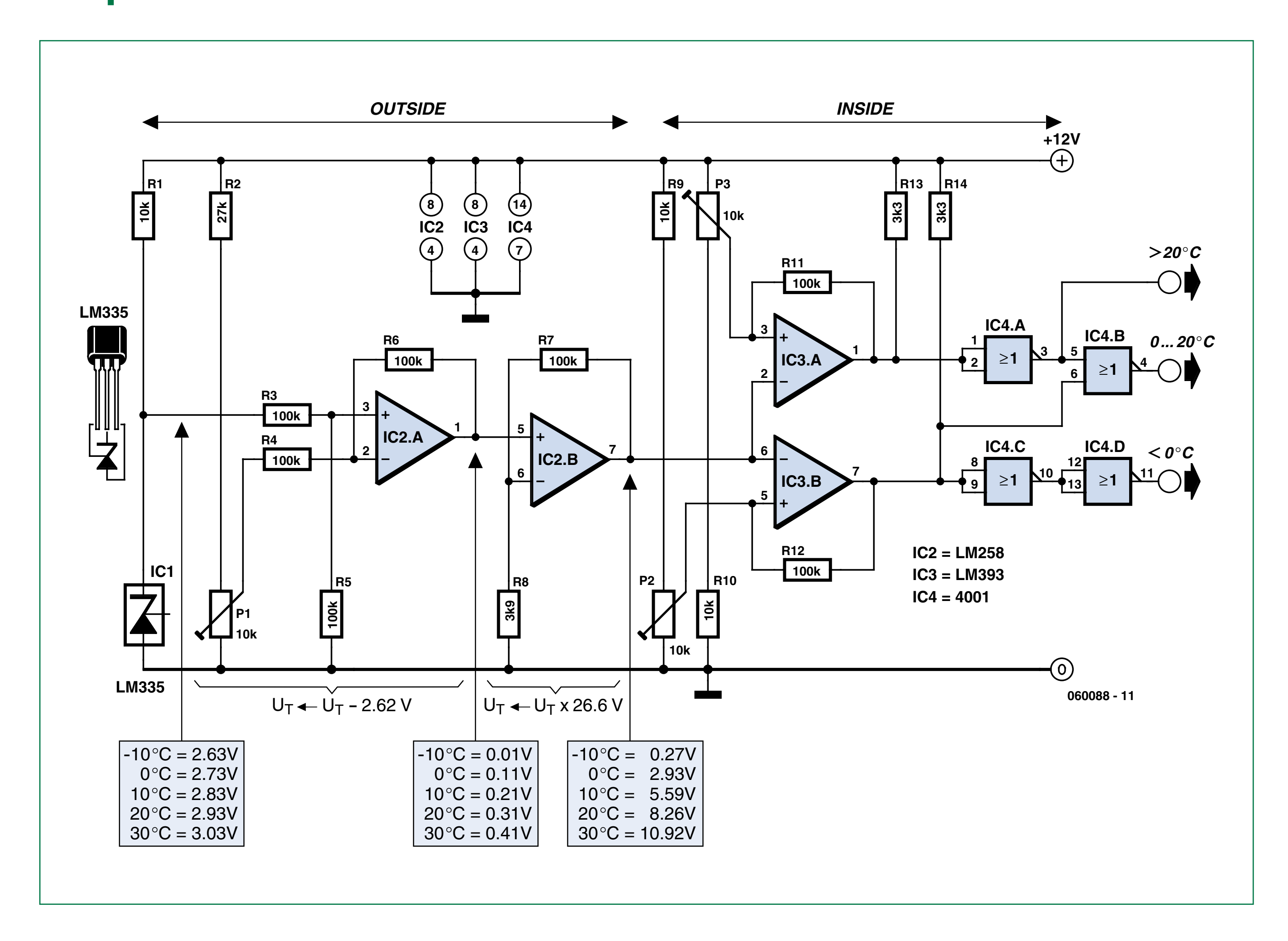


**Figure 9. Building the electronics into a ceiling light. A modified 'electronic transformer' and a PLDM can be seen, with the OSTAR LED in the middle.**

# Temperature Switch




**Heino Peters**
**(The Netherlands)**

The LM335 is a low-cost temperature sensor with a range of –40 °C to +100 °C. In this circuit, it is used to show whether the outside temperature is below freezing or above 20 °C. In the first case, you have to worry about icy roads and the outside taps freezing, while in the second case you can open the windows and switch off the heating. You can adjust the switchpoint temperatures to suit your wishes.

The output of the LM335 provides a potential of 10 mV/K. You can obtain the temperature in °C by subtracting 273 from the output value. For example, at an output voltage of 2.98 V the temperature is 25 °C (298 – 273).
In this case, we only need to be able to measure over the range of –5 °C (2.68 V) to +25 °C (2.98 V), which is a span of only 0.3 V. Consequently, we first expand this range using two of the opamps in IC2.

A reference potential of exactly 2.62 V is set using P2. IC2a compares the output voltage of IC1 with the reference potential and passes the difference on to IC2b. The combination of IC2b, R7 and R8 forms a gain block that amplifies this signal by a factor of 27.
As a result, the output voltage over the temperature range of approximately –10 °C to +30 °C is mapped into a voltage range of approximately 0 V to +11 V. Bear in mind that the indicated voltages can vary slightly due to tolerances in the resistor values. Also be sure to use a stabilised 12-V supply, because any fluctuations in the supply voltage will also be amplified by IC2b.

Next, we use two of the comparators in IC3 to determine whether the outside temperature is below freezing or above 20 °C. IC3a and P3 provide the setpoint for around 0 °C, while IC3b and P2 do the same for 20 °C. As it is a bit difficult to precisely set P2 and P3 in practice (you would have to wait until it is 0 °C or 20 °C outside), you can initially set them to the calculated values (2.93 V for P2 and 8.26 V for P3). You can adjust the settings later on if the switchpoints differ too much from the desired temperatures.

Finally, four NOR gates are used to derive three switching signals from the two output signals. These switching signals can be used to drive three LEDs (for example) to indicate which range the temperature lies in. You should preferably use low-current LEDs to avoid overloading the CMOS gates, and connect each of them to ground via a 3.3-kΩ resistor.

It's a good idea to place the left part of the circuit (up to and including IC2b, R7 and R8) indoors and the right part outdoors. An interconnecting cable of 10 metres will not present any problems. However, you should connect a 100-µF, 16-V capacitor across the supply voltage on the outdoor circuit board.

In principle, you could also use an LM358 in place of the LM258, but its operation is not guaranteed by the manufacture at temperatures below 0 °C.

(060088-1)

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# Omni Pendulum
## The ultimate classroom project

Pavel Grodek (Russia)

**Most people seem to think that the only thing digital electronics is good for is blinking LEDs. After all, everything in this world is "analogue" – and there is no easy to way to interface a microcontroller to the real world without some arcane 'input stage' with amplifiers and filters. Or is there?**




Admit it... most microcontroller-based projects tend to be digital in their nature: some buttons (binary signals), LEDs (binary outputs), maybe a piezo speaker (binary sound output).

This project is different. The microcontroller in it is directly connected to a small coil — and there is nothing else (except, maybe, a power source and some noise suppressing capacitors). And yet it manages to achieve something that's almost impossible with any kind of traditional analogue setup: *perpetual motion*. Well, as long as the batteries last…

### The pendulum

There are two major kinds of pendulum: linear — rotating around the fixed axle, and omni-directional — generally some weight on a bit of string. It could swing in any direction, with any speed and trajectory. The first kind is widely used in clocks – it's easy to detect its exact position and push it just in time with some kind of mechanical device or an electromagnet. The second kind is tricky — there is no easy way to make it swing forever. At some point it will, most probably, travel a round, slowly tightening spiral, and come to rest in the centre position.
If you browse the Web there are a few designs that attempt to make the omni pendulum swing forever with analogue tricks. Basically, you take two hand-wound coils: one to detect the approaching magnetic pendulum, and the other one to push it away as soon as it passes the centre position. Well, they seem to work most of the time, but they are pretty complex, require a lot of fine-tuning, and are not infallible: if you stop the magnet manually or if it rotates in a circle – there is no current in the detector coil and, of course, no signal to the electromagnet. They also tend to be power-hungry and inefficient. Let's design something better — with a microcontroller!

### Hardware

The 'mechanical' part is very easy: take a small rare earth magnet and attach it to a string with one pole pointing down. I've used a fishing line — it lasts longer than a string, and that's important when there are about ten million swings every year! I attached the magnet with a bit of Scotch tape, and it holds well.
The electronic part is a bit more difficult, but still one of the easiest in your

(embedded) life. The minimal version requires only two parts: the microcontroller itself and one coil. Let's do it properly, though, and design it from the ground up. The result is shown in **Figure 1**.

First, we'll select a microcontroller. An ATmega8 chip from a previous project was chosen; they are very cheap and easily available anywhere, even in my country.

To power the project we need some stabilized power source, preferably +5 V DC. It's easy to make one – just buy a 'wall wart' that provides + 8 or more volts for charging or powering some device and use a linear regulator like the LM78L05 or its bigger cousin the LM7805. We don't need a lot of power, about 25 mA in very short bursts, so any kind will do. Don't forget to add a couple of capacitors – one electrolytic on the input and one small ceramic on the output of the stabilizer, as its datasheet indicates.

There is an easier approach, though — if you have a computer with an USB port, it provides a very nice, well-stabilized +5 V, even if a bit noisy. It's also well protected: the USB standard says that it has to survive shorting any of its pins to each other for 24 hours.

Next we'll need a coil. Not just any coil, but we'll certainly be able to use many types. It does not need to have a core — just enough turns of wire (say, a few hundred), so it will produce a good strong signal, and we also want to have some reasonable resistance to limit the current and protect the microcontroller pins. The current that they could survive is indicated in the datasheet — about 25 mA. Ohm's law says that at 5 V we need to have about 200 ohms, so if our coil has less resistance we'll just add a resistor (R1) in series to get the safe total value. For example, if our coil is wound with a very thick wire and has 1 Ω of resistance, we'll just use a resistor close to 200 Ω (the nearest standard value that's easily available is 220 Ω) and it will work just fine.

For the first design a coil was used from an old dead hard drive that moved its head assembly. It was about 100 Ω and easy enough to cut out from the aluminium head frame.

Finally, even though it's not strictly necessary, it's nice to have some UI in the form of buttons, LEDs, etc. Following the KISS approach one button (S1) and one LED (D1) are available optionally for h/w as well as used in the source code (available free on the

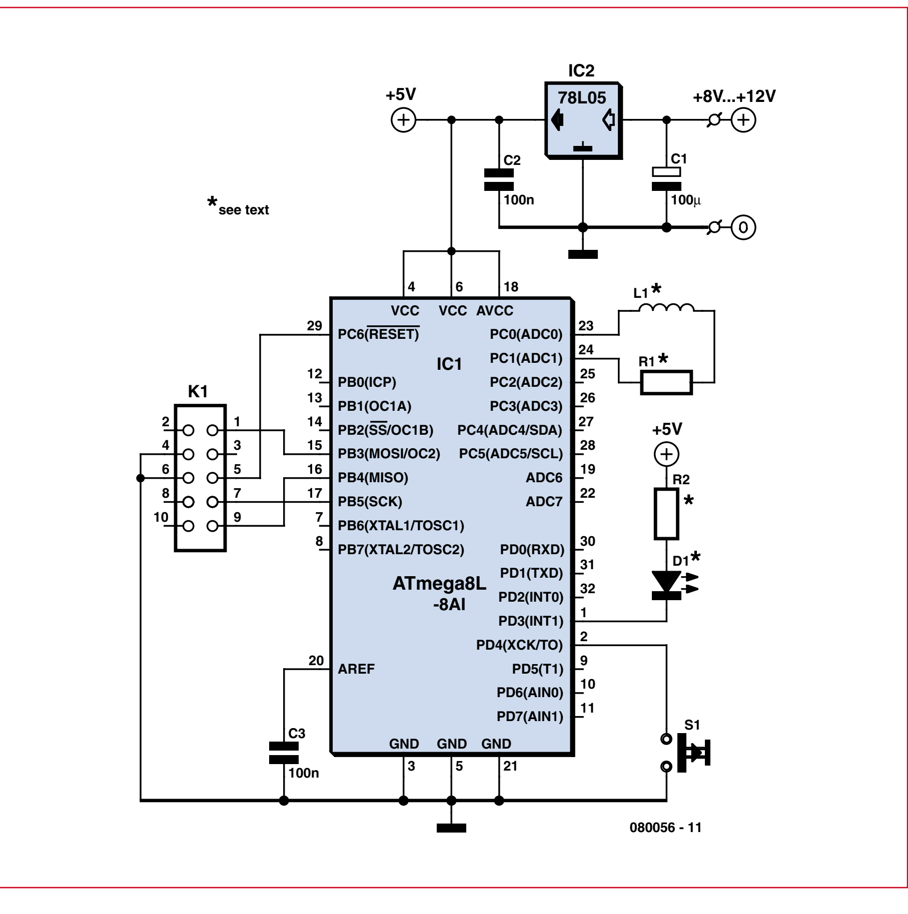



**Figure 1. Circuit diagram of the Omni Pendulum controller. By clever programming of the AT micro, the coil is used as an actuator as well as a sensor!**

Elektor website [1]). The LED is connected using series resistor R2 to limit the current – depending on the LED colour you'll need 220 Ω (for white and blue ones) or 470 Ω to 1000 Ω for good old red/green/yellow ones.

Next comes the programming connector, K1. After all, you will certainly like to play with this circuit a lot, adding new features and modifying them. So, while it's possible to simply solder the five wires where they should go and cut them later, it's a good idea to install a connector.

And, finally, it's recommended in the ATmega8 datasheet to install some 0.1 µF capacitors between the Vcc and GND pins of the microcontroller. It's not strictly necessary, it will almost certainly work without them, but it's better to be safe than spend hours trying to debug the device.

So, while the minimal version takes its power straight from the USB port and has no external parts except for the coil, if you want to mod & tweak this circuit, it would be useful to build it on a breadboard or to make a small PCB for it. The PCB artwork files (designed by the author) are available as a free download [1].

## Programmer

If you have never programmed a microcontroller before – well, it's a good time to start! You can buy some AVR in-system programmer or build your own. If your computer still has an LPT port, the programmer could be as simple as five wires with series resistors of, once again, about 220 Ω. In this case you'll need to learn a bit about the innards of the Avrdude program that comes with WinAVR and actually programs your chip. It's certainly not difficult, but if you want to have it even easier – just buy a commercial programmer.

## Software

First we'll have to download and install two things: AVR Studio [2] and WinAVR [3]. They will find each other during installation and provide an environment where you will be able to write your C code, compile, emulate and debug it, and then program your final result into a real device.

Create a new project, import the

*OmniPendulum.c* file that you downloaded – and that's it. Read about setting the fuses to get 8 MHz from the internal RC oscillator and learn how to compile and upload the code, and you are good to go. Let's see what's inside the code and how it all works.

The coil is connected to two pins. They could be used as digital outputs, of course, and that's what we do to power the coil and push or pull the magnet. But they could also be used as analogue inputs – we can read the voltage that's generated in the coil by the moving magnet. It's very small, of course, so if our coil doesn't have enough turns, you may want to get a microcontroller that has an amplifier built in (ATtiny25, 45, 85, or ATmega16 are all good examples) and add its initialization to the code. But it's easy enough to find a coil that would generate enough voltage, just look for more turns.

What we do is program the pins as analogue inputs, and keep reading the voltage. If we receive some non-zero value there (the exact value depends on the coil, of course) then here's our magnet! The physics says that the magnet generates the current first in one direction, as it approaches, and then in reverse, as it flies away. We want to push the magnet as soon as it crosses the central point, so we are trying to detect the second situation (by measuring at the appropriate pin and grounding the other one).

Now, as soon as we have detected the magnet where we want it, we can push it. To do that we set both pins to outputs and output +5 V to one side of the coil while grounding the other side. Then we pause for a short time (actually, pushing) and then switch the current off and return to watching.

## Installation

I've chosen to install the pendulum in IKEA shelf case and hide the circuitry, so it looks like a 'perpetual motion' device. To do that I removed a board from the shelf, and used a router to make a cavity (not a through hole of course). The coil is located only a few millimetres from the magnet, and that's enough for good readings and strong pushes. Nothing is visible from the upper side, and little enough is visible from below to fool most people. The **photo sequence** printed here tells the story, also of the PCB making and alternatives.

One interesting side effect of mounting this way is the asymmetrical movement obtained by tying the fishing line around the board above, see the sketch in **Figure 2**. When a pendulum is supported in this way it doesn't oscillate in any direction indifferently, instead it wants to go in some complex orbits that relate to the famous Lissajous curves. Google the web for 'harmonographs' (not hormono…).

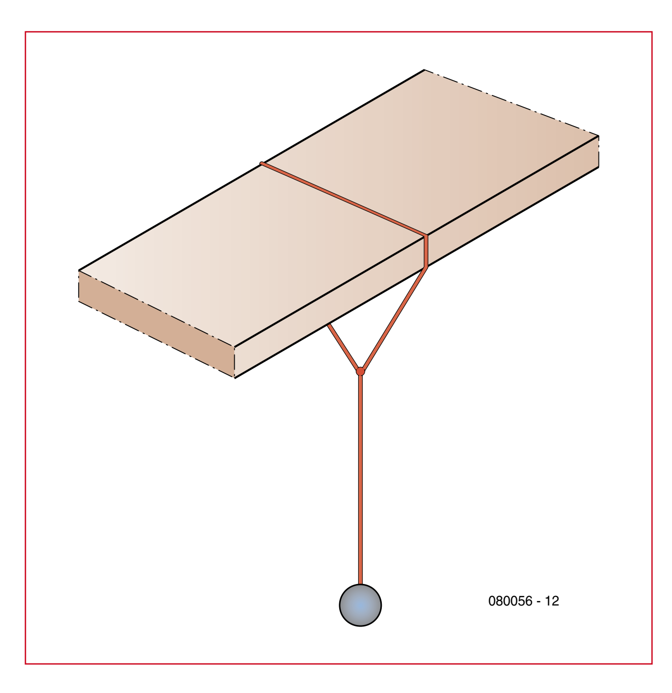



**Figure 2. Simplified graphics illustrating a pendulum support that gives oscillating motion of the magnet.**

If you want to have a 'real omni pendulum' you may want to put a nail or a hole in the top support and tie a string to that. It would produce some interesting patterns, but they would change slowly and most of the time will look less attractive. The asymmetrical support gives more predictable movements, but keeps them changing constantly. It's your choice — what you like best.

## Tricks

It's certainly nice to use one coil for both purposes (so our digital design is ahead of the game already) but it's even better to add some clever tricks so the magnet never stops. If it goes in a circle (or, in fact, a slowly tightening spiral) it will not induce any noticeable current in our coil, so we will not notice that it's stopped. If someone stops the magnet just to see what happens, it's essentially the same problem. And, finally, if there is no electricity for a while — the magnet will stop and the microcontroller, as soon as starts up, will have to start the swings again somehow.

To do that we can simply wait for some time (say, five seconds – about four times as long as it normally takes my pendulum to swing), and if there were no readings all that time – well, we can assume there is some problem and perform the 'emergency startup'. One push is not strong enough, so the simplest method would be to execute a blind series of forceful pushes and pulls with a reasonable frequency. If they are strong enough – they will make the magnet swing wide enough to register normally and then to be pushed exactly right. That's what the current code does, and it works very nice. Of course, there are some smarter methods discussed in the **Mods inset** – but this one is certainly good enough.

As you remember, we have added some extra things, a button and a LED. We can make a simple game, let the user try and beat the microcontroller! As soon as someone pushes the button, the microcontroller detects this and switches to manual mode. It will time out back to automatic in 20 seconds after the last button press, of course. In the manual mode the coil is active and repels the magnet as long as the button is held down. Even with this forceful method it's rather difficult to make the pendulum swing as wide as in automatic mode (where repulsion is only 50 ms long). The LED blinks to indicate the detection and repulsion, and it can be switched on and off by holding the button for a few seconds.

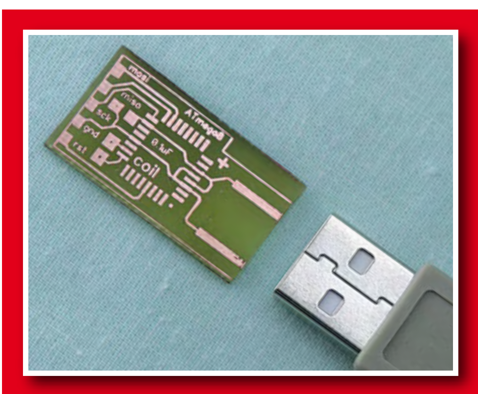
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## Internet Links

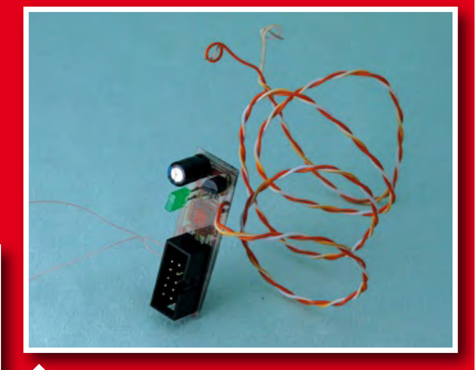
[1] www.elektor.com/080056

[2] www.atmel.com/dyn/products/tools_card.asp?tool_id=2725

[3] http://winavr.sourceforge.net/



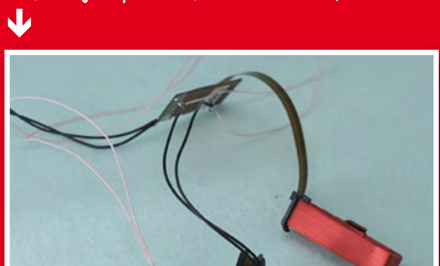
The minimal version of the board, not yet populated, next to an USB connector for size comparison.



Alternate, 'full' version of the board. From top to bottom: input capacitor, 78L05, LED, power supply wire, (transparent) controller on the other side, programming connector. To the left is a coil wire. The button is not installed; it should be attached by another wire and placed conveniently (two holes for it are visible just below the 78L05).

The wire with the magnet on it installed in the IKEA bookshelf case (wire and magnet highlighted for clarity).

Minimal version, with two different coils (the red one, being only 4 ohms, needs a resistor).





View from below; the board and the coil are secured in the routed hole and slot.

## Mods — over 2 U

Well, the device works and it's a lot of fun to see it always swinging without any visible means of propulsion. What's next? It's a perfect platform for experimenting with your first microcontroller project. Nothing could be simpler or easier, and yet it's full of possibilities.

- Make the magnet stop at will by reversing the process and repelling the magnet as it approaches and then attracting it as it flies away;
- Position multiple coils below the magnet and control them to achieve a particular trajectory;
- Make it a full-scale game! Add a few constraints to limit the repelling time and see if you could still achieve a pendulum action (the microcontroller, of course, works perfectly with extremely small repelling times; could a human beat it?), implement 'difficulty levels' by shortening the pulses as the game progresses;
- Make the pendulum react (using some other sensors) to its environment: swing less in the dark, more when it's hot, etc...
- Add a tiny piezo speaker (no extra components are required, just the speaker itself) and make a metronome;
- Add some means of reporting: a UART or an LCD, and discover for yourself what exactly happens in the brief time of interaction between the coil and the magnet;
- Improve the efficiency — use the inductor's properties: select a low-resistance coil, put some current in it (rapidly; a few microseconds only, while the induction limits the current growth!) and then immediately short it to produce a longer push with minimal energy requirements (it would work from batteries for months!);
- Put a plate of fine sand below it and attach some kind of small 'feeler' (a bit of fishing line, for example) and enjoy the beautiful ever-changing patterns;
- Use some clever mathematics to detect the resonant frequency of your pendulum in real time and modify the startup sequence to start very slowly and gradually — it will look as if the pendulum starts by itself.
- Good luck and have fun — that's what electronics is all about!

# Hexadoku

## Puzzle with an electronics touch

**Addicts to the Hexadoku puzzle, here is another bunch of numbers (called 'hexadecimal' by pundits) to contend with using pencil, rubber and some brain activity. Go for it and try to enter the right hex numbers in the boxes. Send us your solution and enter a prize draw for an E-blocks Starter Kit Professional and three Elektor Shop vouchers.**

The instructions for this puzzle are straightforward.

In the diagram composed of 16 x 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines).

A number of clues are given in the puzzle and these determine the start situation.

All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes. The puzzle is also available as a **free download** from our website.

### SOLVE HEXADOKU AND WIN!

Correct solutions received enter a prize draw for an

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worth **£249**



and three **Elektor SHOP Vouchers** worth £40.00 each.

We believe these prizes should encourage all our readers to participate!

The competition is not open to employees of Elektor International Media, its business partners and/or associated publishing houses.

### PARTICIPATE!

Please send your solution (the numbers in the grey boxes) by email to:

**editor@elektor.com - Subject: hexadoku 12-2008** (please copy exactly).

Include with your solution: **full name and street address.**

Alternatively, by fax or post to: **Elektor Hexadoku**
**Regus Brentford - 1000 Great West Road - Brentford TW8 9HH**
**United Kingdom - Fax (+44) 208 2614447**

The closing date is **1 January 2009.**

### PRIZE WINNERS

The solution of the October 2008 Hexadoku is: **AB749**.

The **E-blocks Starter Kit Professional** goes to:
Terje Daleng (N).

An **Elektor SHOP voucher worth £40.00** goes to:
David Chester (USA); Lizzie Lever (UK); Ciril Zalokar (SLO).

**Congratulations everybody!**

| | | | | | | | | | | | | | | | |
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| | | | D | F | | | 5 | | 8 | 9 | E | 4 | | | 1 |
| 0 | E | D | 9 | 7 | | 5 | 6 | 8 | | | | | | | |
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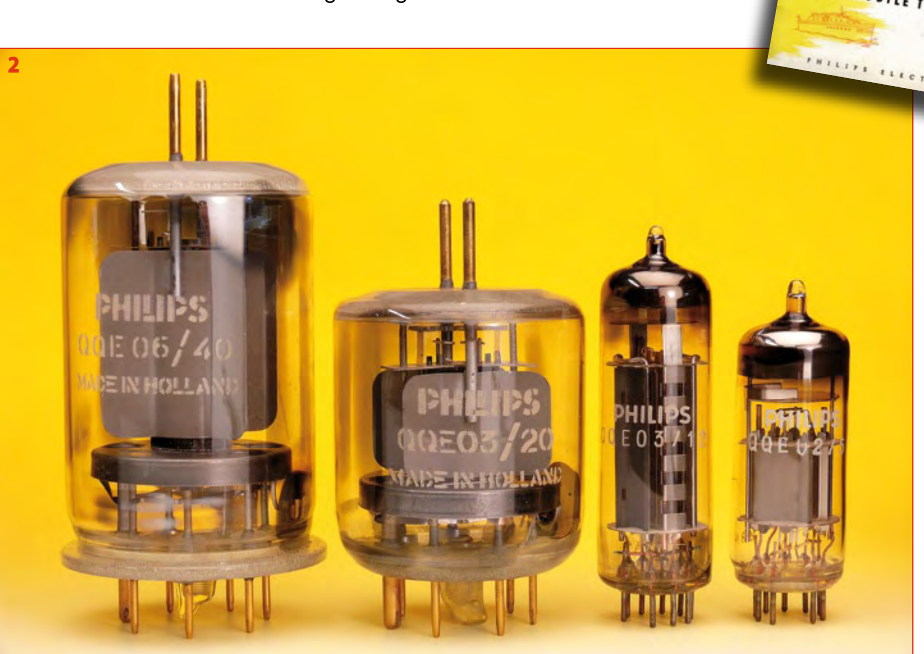
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| 5 | 1 | 0 | 7 | 9 | D | B | E | 2 | 3 | 4 | F | 8 | A | C | 6 |
| C | D | E | A | 3 | 7 | 4 | 2 | 8 | 6 | B | 1 | 9 | 0 | 5 | F |
| 1 | F | C | 4 | 2 | 3 | 0 | 6 | A | 8 | E | B | 7 | 9 | D | 5 |
| E | 9 | D | 6 | A | B | 1 | 5 | C | 7 | 0 | 3 | 2 | 4 | F | 8 |
| 2 | B | A | 8 | 4 | E | 7 | D | 6 | F | 5 | 9 | C | 1 | 0 | 3 |
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| 3 | 0 | 1 | F | D | 8 | 9 | 7 | B | 4 | C | 6 | 5 | E | A | 2 |
| 7 | E | 4 | 9 | B | A | 6 | 1 | D | 2 | 8 | 5 | F | C | 3 | 0 |
| D | A | 7 | E | 8 | 6 | 2 | B | 5 | C | F | 0 | 4 | 3 | 9 | 1 |
| 4 | 8 | F | 1 | 7 | 0 | D | A | 9 | B | 3 | 2 | 6 | 5 | E | C |
| 9 | 6 | 2 | 0 | E | 5 | 3 | C | 1 | D | 7 | 4 | A | F | 8 | B |
| B | C | 5 | 3 | 1 | 4 | F | 9 | E | A | 6 | 8 | 0 | D | 2 | 7 |

# 'QQE' RF power double tetrodes (ca. 1950)

**Jan Buiting**
**(Elektor UK editorial)**

Happy with the good response I got to two previous Retronics stories about little known valves like the Dekatron and E1T, I decided to dig out some more 'rare glass'.

The principle of the push-pull power output stage is well known for its application in audio amplifiers using valves like the EL34 (6CA7), 6L6 or EL84 (6BQW5) to mention just three. And it works for RF too using golden oldies like the 807 beam tetrode which will happily work up to 30 MHz or so. Drive two of these in antiphase using class C(-ish) biasing, link the anodes through the output coil and apply decoupled HT (high tension) to the coil's centre tap. RF output power is then available from a 'tank circuit', which basically is no more than a few turns of wire inductively coupled to the anode coil.




2

Probably as a result of the increasing significance of VHF (i.e. frequencies above 30 MHz) and centimetre waves (up to 1 GHz), designers at various radio valve industries soon were able to squeeze two RF tetrodes into a single glass envelope, usually with the anode pins at the top. The construction eliminated to a large extent those horrid stray capacitances and inductances associated with two individual 'audio' valves (like the 807) in push-pull configuration.

The type 832A (CV788) dual beam RF power tetrode (**Figure 1**) could be used up to about 250 MHz but it was a pain to keep stable even in CW. At higher voltages and frequencies above 100 MHz, the valve behaved erratically. The cause was known: parasitic cross-inductance between the two screen grids in the valve would set up perfect conditions for oscillation high up in the VHF band! Cancelling out these parasitics required an advanced technique called external neutrodynisation (or 'neutralisation') — don't try this at home!.

Around 1950, it was discovered that *frequency-independent* neutralisation could be implemented *inside* RF double tetrodes to achieve VHF-plus frequencies without stability problems. The trick: two small right-angled rods, each welded onto the supporting rod of one control grid, to act as a minute (<0.08 pF) capacitance with the anode of the other tetrode [1]. In 1951 Philips Holland were the first to put this into mass production with their QQE series, which knocked the socks off the old 832As and 829Bs from the US.

For nomenclature we have: QQExx/yy where Q = tetrode, E = indirectly heated oxide cathode, xx = anode voltage in kV; yy = output power in watts in class C. Thus, QQE03/20 = 300 V, 20 W RF out. These are 'conservative ratings' — in practice, the valve can be made to do considerably better.

By about 1965 the series was consolidated to comprise the QQE02/5, QQE03/12, QQE03/20 and QQE06/40 — see the family portrait in **Figure 2**. The 03/20 and 06/40 have a special design using anode pins at the top and gold-plated pins at the base. The 02/5 and 03/12 are less conspicuous with their ordinary 9-pin noval base. The 02/5 has remained a rare bird while the other three achieved stardom among RF fans of the transmitting variety, and today adorn mantelpieces or just the highest bookshelf in the radio shack, often fitted in their specially designed ceramic 'septar' sockets. All family members except the 03/12 can be used as high up as 430 MHz.

These valves are extremely rugged, long lasting and reliable, witness their use in 1950s/1960s PMR base and mobile equipment, in some cases with transistors driving them. Genuine Philips QQEs were produced well into the 1970s with lots of clones (CV/QQV/JAN) and special quality versions (SQ/YL) also appearing on the market. Remarkably I've never seen a valve tester supporting the QQE03/20 or 06/40, but then, live testing is a simple matter — plug in, retune and see how many watts of RF out you get. All will be fine for years to come if you get above 70% or so of the value found in the manual. Stay well clear of the HT though!

(080771-I)

**[1] Double Tetrode QQE06/40 for Mobile Transmitting Equipment:**
http://frank.pocnet.net/sheets/084/q/QQE06-40.pdf

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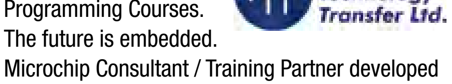
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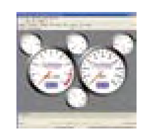
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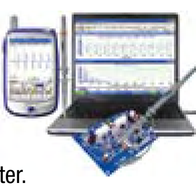


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# Going Strong

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### Elektor SMT Reflow Oven

(October 2008)

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*Size: 418 x 372 x 250 mm (16.5 x 14.6 x 10 inch)*

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### Remote control by Mobile Phone

(November 2008)

Remote control using mobile phones and SMS (Text Messaging) is in great demand but many systems on sale suffer from imperfections. This ingenious new design combines powerful capabilities with low technical overheads. It has programmable AC mains switching outlets plus status reports by text message and alarm-activated delivery of GPS data. Remote control by mobile was never easier, cheaper or more reliable!

*Kit of parts, incl. PCB, programmed controller and all parts*

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### Communicating with CAN

(October 2008)

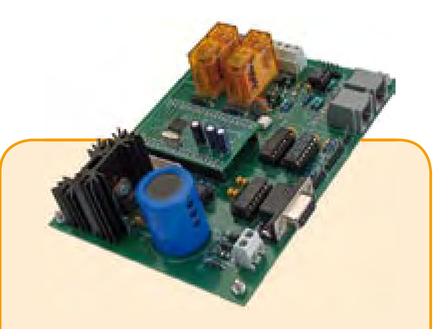
The CAN (Controller Area Network) protocol was originally developed for use in the automotive sector. It is now over 20 years old, but is still frequently used these days. It was specially designed for use in environments where you have a lot of electromagnetic interference. Despite the fact that the CAN protocol is a serial protocol, it can't just be connected to (the serial port of) a computer. The all-round USB-CAN adapter described in last month's Elektor is a compact and simple solution. With the help of the accompanying software you can follow all data communications taking place and carry out operations such as filtering and storage at the flick of a (mouse) switch.

*PCB, partly populated*

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## DCC Command Station

(September 2008)

Electronics is making more and more inroads into the domain of model trains. Trains are now controlled with digital codes, and in many cases the entire system can be operated from a computer. Elektor presents a design for the device that forms the heart of a digitally controlled model railway: the DCC Command Station. The computing power in this design is provided by a highperformance ARM7 processor.

*Kit of parts incl. programmed ARM module*

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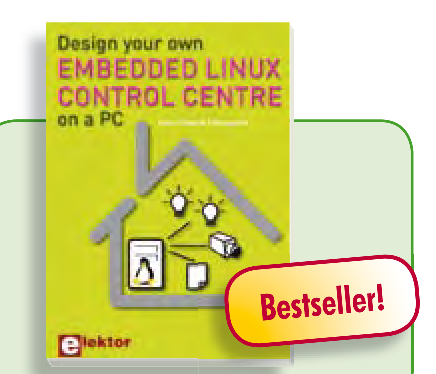

## DigiButler

(May & April 2008)

A low-cost home automation server based on a Freescale Coldfire 32-bit microcontroller. The project has been designed with open source in mind and doubles as a powerful Coldfire development system using free CodeWarrior software from Freescale. DigiButler activates electrical appliances in and around the home, accepting on/off commands from a WAP phone, through an Ethernet network or via a webpage at an allocated IP address and with full access security.

*Kit of parts including SMD-stuffed PCB, programmed microcontroller, all leaded parts and CD-ROM containing both Elektor articles, TBLCF documentation, datasheets, application notes and source code files.*

Art. # 071102-71 • £29.00 • US$ 58.00




**A DIY system made from recycled components**

## Design your own Embedded Linux control centre on a PC

This book covers a do-it-your-self system made from recycled components. The main system described in this book reuses an old PC, a wireless mains outlet with three switches and one controller, and a USB webcam. All this is linked together by Linux. This book will serve up the basics of setting up a Linux environment – including a software development environment – so it can be used as a control centre. The book will also guide you through the necessary setup and configuration of a webserver, which will be the interface to your very own home control centre. All software needed will be available for downloading from the Elektor website.

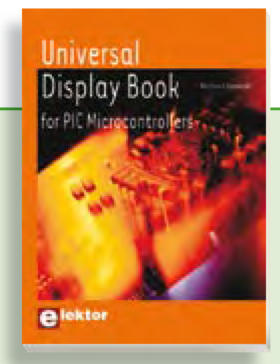
234 pages • ISBN 978-0-905705-72-9
£24.00 • US$ 48.00

### More information on the Elektor Website:

# www.elektor.com

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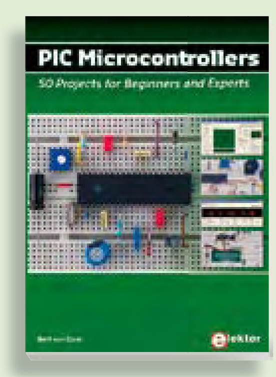




**From LED to graphical LCD**

## Universal Display Book for PIC Microcontrollers

This book begins with simple programs to flash LEDs, and eventually by stages to use other display indicators such as the 7-segment and alphanumeric liquid crystal displays. As the reader progresses through the book, bigger and upgraded PIC chips are introduced, with full circuit diagrams and source code, both in assembler and C. A tutorial is included using the MPLAB programming environment, together with the PCB design package and EAGLE schematic to enable readers to create their own designs.

192 pages • ISBN 978-0-905705-73-6
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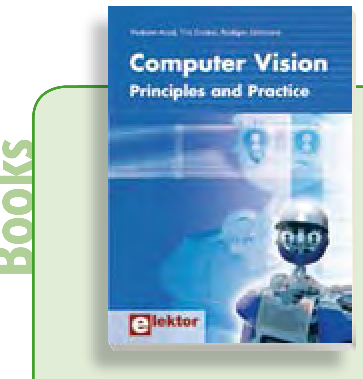

**Silent alarm, poetry box, night buzzer and more**

## PIC Microcontrollers

This hands-on book covers a series of exciting and fun projects with PIC microcontrollers. You can built more than 50 projects for your own use. The clear explanations, schematics, and pictures of each project on a breadboard make this a fun activity. The technical background information in each project explains why the project is set up the way it is, including the use of datasheets. Even after you've built all the projects it will still be a valuable reference guide to keep next to your PC.

446 pages • ISBN 978-0-905705-70-5
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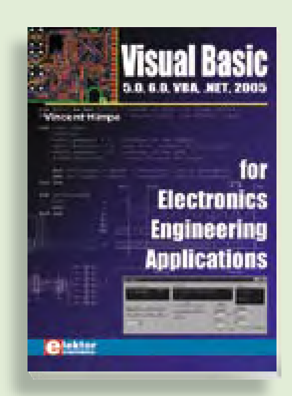



Principles and Practice

## Computer Vision

Computer vision is probably the most exciting branch of image processing, and the number of applications in robotics, automation technology and quality control is constantly increasing. Unfortunately entering this research area is, as yet, not simple. Those who are interested must first go through a lot of books, publications and software libraries. With this book, however, the first step is easy. The theoretically founded content is understandable and is supplemented by many examples.

320 pages • ISBN 978-0-905705-71-2
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5.0, 6.0, VBA, .NET, 2005

## Visual Basic for Electronics Engineering Applications

This book is targeted towards those people that want to control existing or self-built hardware from their computer. After familiarizing yourself with Visual Basic, its development environment and the toolset it offers are discussed in detail. Each topic is accompanied by clear, ready to run code, and where necessary, schematics are provided that will get your projects up to speed in no time.

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Software Tools & Hardware Tips

## Ethernet Toolbox

This CD-ROM contains all essential information regarding Ethernet interfaces! Ethernet Toolbox includes a collection of datasheets for dedicated Ethernet interface ICs from many different manufacturers. It provides a wealth of information about connectors and components for the physical layer (PHY) and specific software tools for use with the Ethernet (Software). To help you learn about the Ethernet interfaces, we have compiled a collection of all articles on this topic that have appeared in Elektor and complemented them with additional documentation and links to introductory articles on Ethernet interfaces. The documents are PDF files.

ISBN 978-90-5381-214-3 • £19.50 • US$ 39.00

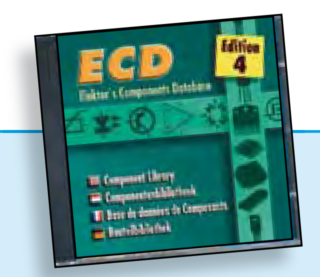



Modern technology for everyone

## FPGA Course

FPGAs have established a firm position in the modern electronics designer's toolkit. Until recently, these 'super components' were practically reserved for specialists in high-tech companies. The nine lessons on this courseware CD-ROM are a step by step guide to the world of Field Programmable Gate Array technology. Subjects covered include not just digital logic and bus systems but also building an FPGA webserver, a 4-channel multimeter and a USB controller. The CD also contains PCB layout files in pdf format, a Quartus manual, project software and various supplementary instructions.

ISBN 978-90-5381-225-9 • £14.50 • US$ 29.00




More than 68,000 components

## ECD 4

The program package consists of eight databanks covering ICs, germanium and silicon transistors, FETs, diodes, thyristors, triacs and optocouplers. A further eleven applications cover the calculation of, for example, LED series droppers, zener diode series resistors, voltage regulators and AMVs. A colour band decoder is included for determining resistor and inductor values. ECD 4 gives instant access to data on more than 68,000 components. All databank applications are fully interactive, allowing the user to add, edit and complete component data. This CD-ROM is a must-have for all electronics enthusiasts.

ISBN 978-90-5381-159-7 • £17.50 • US$ 35.00




All articles published in 2007

## Elektor 2007

This CD-ROM contains all articles published in Elektor Volume 2007. Using the supplied Adobe Reader program, articles are presented in the same layout as originally found in the magazine. An extensive search machine is available to locate keywords in any article. The installation program now allows Elektor year volume CD-ROMs you have available to be copied to hard disk, so you do not have to eject and insert your CDs when searching in another year volume. With this CD-ROM you can produce hard copy of PCB layouts at printer resolution, adapt PCB layouts using your favourite graphics program, zoom in / out on selected PCB areas and export circuit diagrams and illustrations to other programs.

ISBN 978-90-5381-218-1 • £17.50 • US$ 35.00

CD-ROMs

Prices and item descriptions subject to change. E. & O.E

# Product Shortlist

| December 2008 (No. 384) | £ | US$ |
|---|---|---|
| **PLDM** | | |
| 071129-1 ...... Printed circuit board | 5.80 | 9.50 |
| **Hi-fi Wireless Headset** | | |
| 080647-1 ...... Printed circuit board: Transmitter | 7.90 | 15.80 |
| 080647-2 ...... Printed circuit board: Receiver | 7.90 | 15.80 |
| **LED Top with Special Effects** | | |
| 080678-71 .... Kit of parts incl. SMD-stuffed PCB and programmed controller | see www.elektor.com | |
| **November 2008 (No. 383)** | | |
| **Motorised Volume Pot** | | |
| 071135-41 .... Programmed controller ATMEGA8-16PU | 5.90 | 11.80 |
| **Speed Camera Warning Device** | | |
| 080615-1 ...... Printed circuit board | 15.50 | 31.00 |
| 080615-41 .... Programmed controller PIC16F876A-I/SO | 11.80 | 23.60 |
| **Remote Control by Mobile Phone** | | |
| 080324-1 ...... Printed circuit board | 17.80 | 35.60 |
| 080324-41 .... Programmed controller ATMEGA8-16PU | 5.90 | 11.80 |
| 080324-71 .... Kit of parts | 54.00 | 99.00 |
| **Tracking Hot Spots** | | |
| 080358-1 ...... Printed circuit board | 9.10 | 18.20 |
| **ATmega meets Vinculum** | | |
| 071152-91 .... VDIP1 module | 22.50 | 45.00 |
| **October 2008 (No. 382)** | | |
| **Communicating with CAN** | | |
| 071120-71 .... PCB, partly populated | 54.90 | 109.80 |
| **Elektor SMT Precision Reflow Oven** | | |
| 080663-91 .... Ready to use oven (230VAC only) | 882.00 | 1525.00 |
| **Multi-purpose GPS Receiver** | | |
| 070309-41 .... Programmed controller PIC18F2520 | 11.60 | 23.20 |
| **ATM18 Relay Board and Port Expander** | | |
| 071035-72 .... Relay PCB with all components and relays | 36.90 | 73.80 |
| 071035-95 .... Port Extension PCB, populated with SMD | 13.40 | 26.80 |
| **RF Sweep Frequency Generator / Spectrum Analyser** | | |
| 040360-41 .... Programmed controller ATmega8535 | 21.80 | 43.60 |
| **September 2008 (No. 381)** | | |
| **DCC Command Station** | | |
| 070989-71 .... Kit of parts incl. programmed ARM module | 88.50 | 177.00 |
| **July/August 2008 (No. 379/380)** | | |
| **Solar-powered Automatic Lighting** | | |
| 080228-41 .... Programmed controller PIC12C671 | 9.00 | 18.00 |
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| 070821-41 .... Programmed controller PIC16F676-20I/P | 5.90 | 11.80 |
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| **Operating Hour Counter** | | |
| 070349-41 .... Programmed controller PIC12F683 | 5.90 | 11.80 |
| **Energy-efficient Backlight** | | |
| 080250-41 .... Programmed controller ATmega32 | 22.50 | 45.00 |
| **Deluxe '123' Game** | | |
| 080132-41 .... Programmed controller ATmega8-PU | 9.00 | 18.00 |
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| 080118-41 .... Programmed controller ATtiny13 | 4.90 | 9.80 |
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| 071037-41 .... Programmed controller AT90S8515P | 14.90 | 29.80 |
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| **Simple USB AVR-ISP Compatible Programmer** | | |
| 080161-41 .... Programmed controller ATmega8-16AU | 11.90 | 23.80 |
| **Intelligent Presence Simulator** | | |
| 080231-41 .... Programmed controller PIC12C508 | 5.90 | 11.80 |

# Bestsellers

| Category | # | Title | Reference | £ | US$ |
|---|---|---|---|---|---|
| Books | 1 | Embedded Linux Control Centre | ISBN 978-0-905705-72-9 | £24.00 | US$ 48.00 |
| Books | 2 | Universal Display Book | ISBN 978-0-905705-73-6 | £23.00 | US$ 46.00 |
| Books | 3 | PIC Microcontrollers | ISBN 978-0-905705-70-5 | £27.95 | US$ 55.90 |
| Books | 4 | Computer Vision | ISBN 978-0-905705-71-2 | £32.00 | US$ 64.00 |
| Books | 5 | 309 Circuits | ISBN 978-0-905705-69-9 | £20.95 | US$ 41.90 |
| CD-ROMs | 1 | FPGA Course | ISBN 978-90-5381-225-9 | £14.50 | US$ 29.00 |
| CD-ROMs | 2 | ECD 4 | ISBN 978-90-5381-159-7 | £17.50 | US$ 35.00 |
| CD-ROMs | 3 | Elektor 2007 | ISBN 978-90-5381-218-1 | £17.50 | US$ 35.00 |
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| CD-ROMs | 5 | Home Automation | ISBN 978-90-5381-195-5 | £13.90 | US$ 27.80 |
| Kits & Modules | 1 | DigiButler | Art. # 071102-71 | £29.00 | US$ 58.00 |
| Kits & Modules | 2 | Communicating with CAN | Art. # 071120-71 | £54.90 | US$ 109.80 |
| Kits & Modules | 3 | Elektor SMT-oven | Art. # 080663-91 | £882.00 | US$ 1525.00 |
| Kits & Modules | 4 | SpYder Discovery Kit | Art. # 060296-91 | £9.00 | US$ 18.00 |
| Kits & Modules | 5 | DCC Command Station | Art. # 070989-71 | £88.50 | US$ 177.00 |

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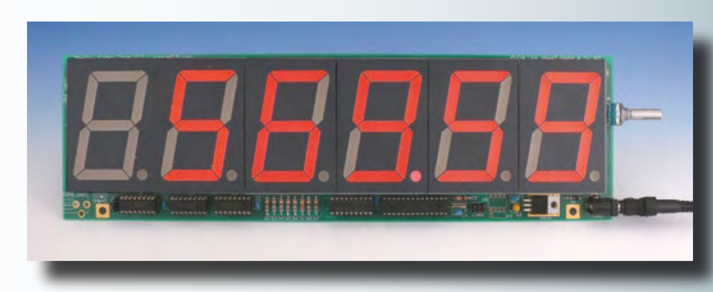



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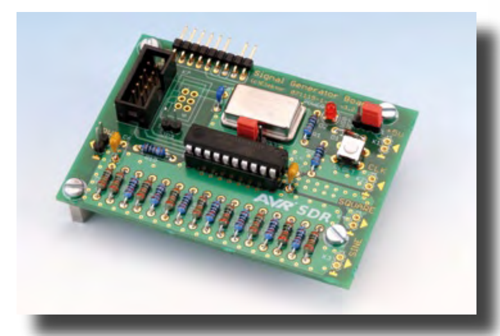
## Mini FM radio

Nowadays miniature FM radios are integrated into all sorts of devices, such as mobile phones and MP3 players. NXP has a very nice little IC in its product line for anyone who wants to build a simple DIY receiver: the TDA7021T. This is a 16-pin SMD, and we have designed a small PCB that makes it easier to put everything together. The full receiver measures only $3.2 \times 2.7$ cm, but it delivers surprisingly good sound quality despite its compact size.



## Meeting cost meter

Especially in these troubled economic times, it's a good idea to avoid wasting money. In many companies, people are trying to work more efficiently in many different ways in order to keep costs (including labour costs) better under control. Long meetings, which can easily consume several hours of the working time of dozens of highly-paid employees, are notorious 'cost guzzlers'. In many cases, meetings can be conducted much more efficiently. To help you keep an eye on the actual meeting cost, we have designed a special meter that constantly shows the total cost of the meeting on a large display. The number of participants and their hourly rates can be set by a knob.




## Stand-alone SDR receiver

In order to receive digital radio broadcasts, you normally need a simple receiver board and a PC to perform the complex decoding operations. Although a few commercial stand-alone SDR receivers are available, the selection is limited and the quality is often only so-so. Starting with the January issue, we will publish a series of articles that show you how to build an SDR receiver using a computer system built around several AVR microcontroller ICs. This series also forms a sort of mini programming course for AVR microcontrollers. A true don't-miss feature!

Article titles and magazine contents subject to change, please check 'Magazine' on www.elektor.com

The January 2009 issue comes on sale on Thursday 18 December 2008 (UK distribution only). UK mainland subscribers will receive the issue between 13 and 16 December 2008.

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September 2007

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December 2008

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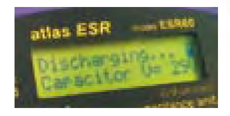
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